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Geology and Mineral Resources of the Womelsdorf Quadrangle

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GEOLOGY AND MINERAL RESOURCES OF THE WOMELSDORF QUADRANGLE, LEBANON, BERKS, AND LANCASTER COUNTIES, PENNSYLVANIA

ABSTRACT

The Womelsdorf quadrangle, located in southeastern Pennsylvania, includes small areas of Lancaster, Lebanon and Berks Counties. The most striking surficial feature in this quadrangle is South Mountain which is underlain primarily by a series of Precambrian gneisses, that have been invaded by granite and closely related rocks. Granite gneiss, including its related varieties, is by far the most abundant of the Precambrian formations in South Mountain. Hornblende gneiss is the second most abundant of the Precambrian formations but usually it has been so extensively intruded and partly assimilated by granite that it cannot be mapped separately. Almost half of the area of South Mountain is mapped as migmatites which have resulted from the invasion of hornblende gneiss by granite. Small amounts of graphitic gneiss and quartz diorite gneiss are found in widely scattered areas within the granite gneiss complex. Pegmatite and metadiabase dikes are numberous on South Mountain. A few pegmatite dikes are as wide as eight feet and only two are known to have contained commercial quantities of muscovite.

The Hardyston Formation of Lower Cambrian age forms the high ridges at the north and west borders of South Mountain. The lower 20 feet of the Hardyston is light-gray to dark-gray, coarse, quartz-pebble conglomerate. Most of the formation above the basal conglomerate is made up of fine- to medium-grained, quartzitic sandstone and sedimentary quartzite.

Directly to the north and west of South Mountain is a low, flat, gently rolling limestone valley called the Lebanon Valley. The carbonate rocks present in this valley range in age from Early Cambrian to Late Ordovician and include two major rock groups, the Beekmantown and Conococheague. Detailed mapping in the Great Valley of Pennsylvania has shown that major limestone and dolomite units can be separated from what was originally called the Beekmantown Formation and Conococheague Formation. John P. Hobson, Jr. in 1957 first named and described four formations within the Beekmantown Group in Pennsylvania. Carlyle Gray and Alan R. Geyer later named and described five separate carbonate members stratigraphically below the Beekmantown Group; in this report it is proposed that these be raised to formational rank.

The major structural feature of this quadrangle is a completely overturned and essentially recumbent fold of carbonate rocks with a fairly thin plate of crystalline rocks and clastic sediments thrust over the

recumbent structure. In many locations the crystallines, clastics, and carbonates are exceedingly sheared and in places nearly mylonitized.

South of the Lebanon Valley and South Mountain lies the Triassic Physiographic Province. Most of the northern part of the Triassic area in the Womelsdorf quadrangle has relatively low relief and is extensively cultivated. The Triassic sediments exposed in this quadrangle are assigne to the upper part of the Newark Group, the Gettysburg Formation, which consists of red shales, red quartzose sandstones, and quartz conglomerates with local bodies of shale conglomerate. Newark Group sediments are composed of detritus which is thought to have been derived from erosion of Paleozoic and Precambrian rocks in immediately adjacent areas. The structure of the Triassic rocks in this quadrangle is a homocline, broadly warped and block-faulted, with a local plunging syncline near the north border. The north border itself, over most of the width of the quadrangle is a major fault with a displacement of several thousand feet. The Triass strata, in general, dip toward the north at angles of from 20 to 50°.

Quaternary deposits composed of angular blocks of Cambrian and Precambrian rocks cover the steep slopes of South Mountain and obscure the contact of Triassic and older rocks nearly everywhere. Recent alluvium is also widespread in the stream valleys.

INTRODUCTION

LOCATION

The Womelsdorf quadrangle is located in southeastern Pennsylvania, between the $40^{\circ}22'30''$ and $40^{\circ}15'$ parallels of north latitude and the $76^{\circ}07'30''$ and $76^{\circ}15'$ meridians of west longitude. The area is bounded by the following four quadrangles: on the east Sinking Springs, on the west Richland, on the south Ephrata, and on the north Strausstown. Small areas of Lancaster, Lebanon, and Berks Counties are included within this quadrangle.

SURFACE FEATURES

The most striking surficial feature is South Mountain (Fig. 1). This mountain comprises about one-third of the total land area within the quadrangle and has a total relief of over 700 feet. Little farming is done because of the rugged nature of the topography and the poor soil developed over these igneous rocks. Much of the countryside is woodland and no major towns are located on the mountain.

Directly to the north and west of South Mountain is a low, flat, gently rolling limestone valley (Fig. 2). This valley is the easternmost extension of the Lebanon Valley, a minor subdivision of the Great Valley

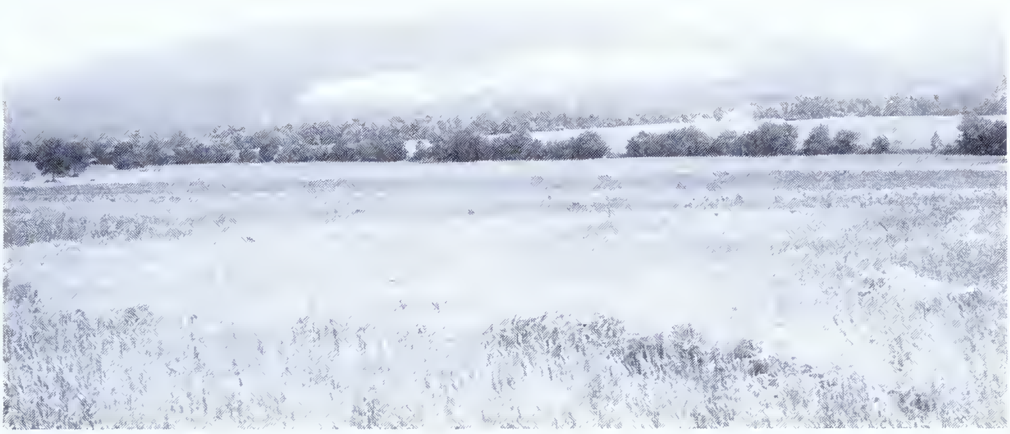


Figure 1. Eagle Peak on South Mountain and North American Refractory Brick Company quarry in Hardyston quartzite. View looking southeast from Lebanon Valley.

Figure 2. View of the Lebanon Valley from South Mountain.

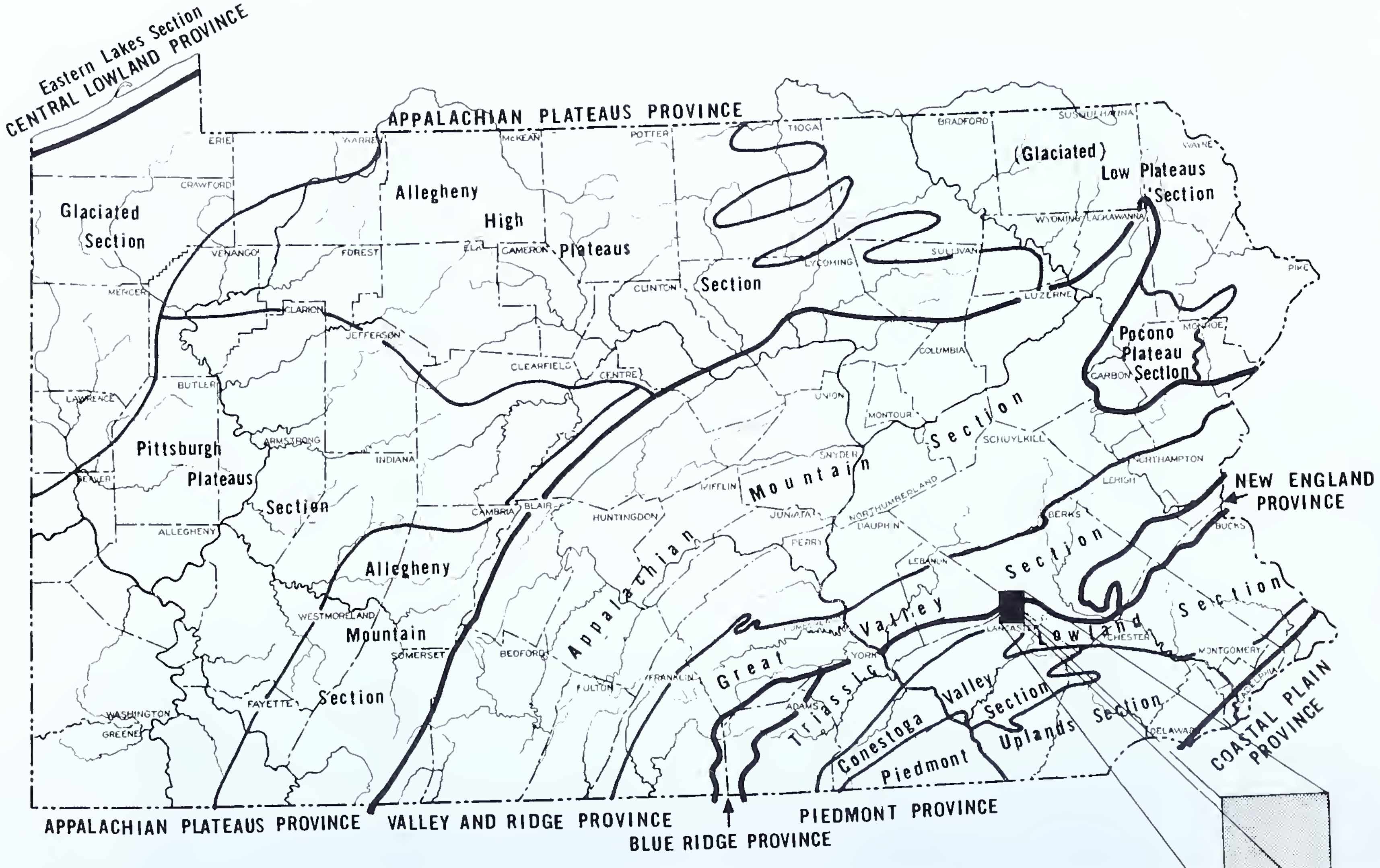


Fig.3. PHYSIOGRAPHIC REGIONS OF PENNSYLVANIA

Section of the Valley and Ridge Physiographic Province in Pennsylvania (Fig. 3). The low topographic relief of the valley is due entirely to the solubility of a thick sequence of limestones and dolomites. Typical physiographic features are disappearing streams, sink holes, and larger collapsed areas. A thick soil over the limestone bedrock makes this valley very fertile and large prosperous farms abound. Only one small area in the northeast corner is representative of the northern part of the Great Valley in Pennsylvania. This area is underlain by shale and at the contact with the limestone rises 125 to 150 feet above the floor of the valley. Shale is much more resistant to erosion in Pennsylvania and therefore stands out as small hills above the limestone and dolomite.

The Triassic Lowland Section of the Piedmont Province lies south of the Lebanon Valley and South Mountain. In this quadrangle the term "lowland" is justified by its low elevation, several hundred feet less than that of South Mountain, although in the Richland quadrangle to the west, the Triassic area is higher than any other part of the quadrangle. Most of the northern part of the Triassic in the Womelsdorf quadrangle has relatively low relief and is extensively cultivated. Laurel Ridge at the eastern edge of the north border area, is formed by resistant conglomerate and is wooded. Along the southern edge the Furnace Hills are underlain by conglomerates and resistant sandstones and are also heavily wooded.

CONTRIBUTORS

When the initial undertaking of this project on the geology of the Womelsdorf quadrangle was begun, it was anticipated that several geologists would be interested in mapping the area. At that time individual geologists were asked to join in a cooperative report.

Dr. Dean B. McLaughlin of the University of Michigan probably has spent more time mapping the geology of the Triassic rocks of Pennsylvania than any other single worker. To him is due the credit for the mapping and interpretation of the Newark Group rocks in this report.

Dr. Tracy V. Buckwalter of the University of Pittsburgh has for many years studied the Hardyston Formation and the Precambrian rocks of southeastern Pennsylvania. Credit for the following interpretation and description of the isolated remnant of these rocks in the Womelsdorf quadrangle is Dr. Buckwalter's.

Dr. Carlyle Gray undertook the study of the Annville Limestone and associated Middle Ordovician limestones while Mr. Alan R. Geyer mapped the Beekmantown Group, Conococheague Group, and Buffalo Springs Formation throughout the quadrangle.

PRECAMBRIAN ROCKS

by

Tracy V. Buckwalter

GENERAL STATEMENT

The Precambrian rocks of South Mountain are nearly identical to those of the Reading Hills in Berks and Lehigh Counties and bear considerable resemblance to those of the highlands of northern New Jersey. They consist fundamentally of a series of older gneisses, in large part metasediments, which have been invaded by granite and closely related rocks

Although the Precambrian rocks of northern New Jersey are farther away from South Mountain than those of the Piedmont province, the New Jersey crystallines resemble the South Mountain rocks much more closely than do those of the Piedmont. Because of the near-identity of the rocks of this area to those of the Reading-Boyertown Hills, several of the earlier published descriptions (Buckwalter, 1953, 1958, 1959) are used here, although some have been considerably elaborated or otherwise modified.

GRANITIC GNEISS

Distribution

Granitic gneiss, including its related varieties, is by far the most abundant of the Precambrian formations. It underlies more than three-fourths of the Precambrian area of South Mountain and has intruded many of the remaining Precambrian rocks. Good outcrops of typical granite gneiss are located in the valley of Mountain Creek near the State Hospital and on the tops of some of the higher hills, particularly on the south side of South Mountain. However, over most of South Mountain, it occurs only as float.

Petrography

Typical granitic gneiss is light buff or bronze to light pink and is fine- to medium-grained. Most of the grains are about one millimeter in diameter. The gneissic structure is in most places illdefined and locally absent. Where present it is caused chiefly by an imperfect parallel orientation of hornblende and its chief alteration product, chlorite. Several outcrops weather into large slabs which break parallel to the weak gneissic structure (Fig. 4). Locally some granitic gneiss weathers into spheroidal boulders.

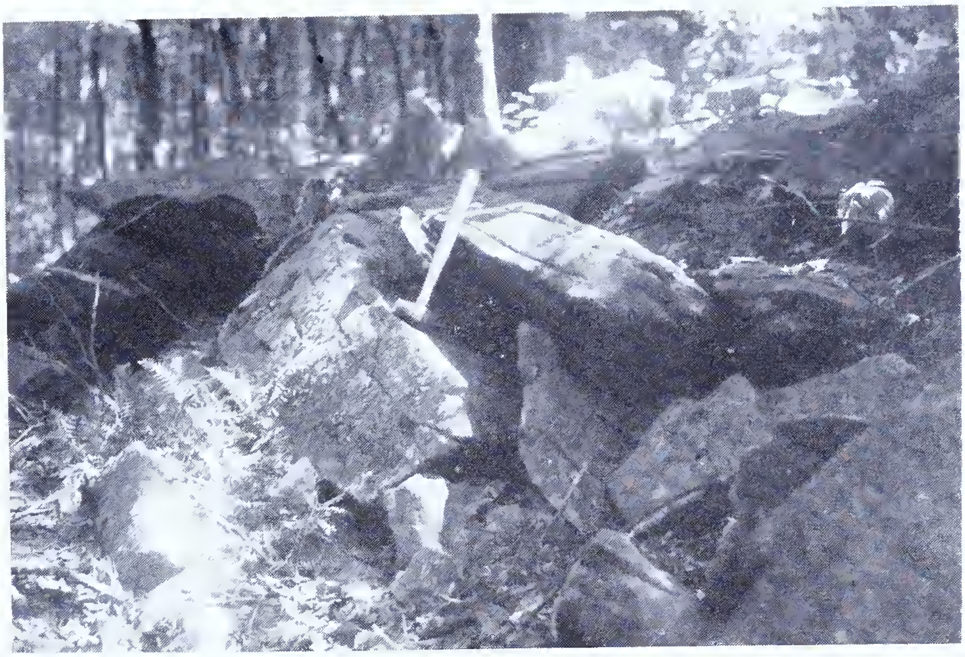


Figure 4. Outcrop of granitic gneiss showing slabby weathering parallel to the weak gneissic structure.

The mineral composition is somewhat variable, but in all the gneiss, microcline, including microcline perthite, comprises about 30 to 60% and quartz 20 to 40%. Plagioclase comprises zero to 40% with a content of 15 to 30% being most common. Orthoclase ranges from zero to 25%, averaging approximately 10%. The most common ferromagnesian mineral is hornblende, which, except in migmatites, rarely exceeds 5% of the rock. It is pleochroic from light yellow green to dark green. It is somewhat less abundant than that of the approximately equivalent "Byram" type hornblende granite gneisses in northern New Jersey, described by Sims (1958), Hague (1956) and others. In some areas where the ferromagnesian content is quite low, the rock is a leucogranite gneiss. A monoclinic pyroxene, probably augite, occurs infrequently and green biotite is very rare. The ferromagnesians are in many places altered to fine-grained aggregates of bright green chlorite and locally to epidote. Accessories include apatite, magnetite, zircon, and ilmenite.

Perthite occurs abundantly in most of the gneiss. It is frequently of the "string type", though in some places is "patch" and "braid". Plagioclase ranges from calcic oligoclase (An24) to sodic andesine (An34). In some localities nearly all feldspar is sericitized and kaolinized, but more commonly plagioclase is altered more intensely than potash feldspar. Most, but by no means all the plagioclase is twinned. Albite twins and some pericline twins are the only types observed. No Carlsbad twins or the rarer, more complex types like Manebach or Baveno twins were found.

According to Turner (1951) and Gorai (1951) a preponderance of albite and pericline twins (rather than Carlsbad or the more complex twins as well as the absence of twinning) suggest that the plagioclase and its twinning is of metamorphic origin. Despite the weak gneissic structure, most of the rock has been at least moderately regionally metamorphosed. This is indicated by numerous sutured contacts, especially of quartz grains, microscopic crushed zones which have been partly recrystallized, mortar structures and by weak elongation of quartz. Hornblende, and much less commonly biotite, show some parallelism. However, a little granitic gneiss shows nearly normal, interlocking, hypidiomorphic igneous texture.

A gneissic, pegmatitic variety of granitic gneiss is common throughout much of the southwest side of South Mountain. This variety is light pink to light gray and varies in grain size from 1.5 millimeters to about 1.5 centimeters. The major minerals are quartz and alkali feldspar. Hornblende and very minor biotite similar to that in the more typical granitic gneiss usually comprises less than five percent of the bulk. They are almost completely chloritized. The gneissic structure is more evident than in typical granitic gneiss and is caused by parallelism of the ferromagnesian minerals and parallelism of elongated quartz grains. At one locality quartz grains are about five times as long as wide.

An unusual sheared variety of granitic gneiss occurs at the south edge of South Mountain near the intersection of the Blainsport-Cocalico road and the road to Robesonia and Wernersville. This gneiss looks much like sheared arkose of the Hardyston Formation in that the quartz is more abundant and the feldspar considerably less abundant than in typical granitic gneiss. The light-gray-brown color and the grain size (0.5 millimeter to 1.0 millimeter) are similar to that in the Hardyston. The nearly schistose, foliate structure is much more prominent than in other granite gneisses. It is caused by a marked parallelism of altered ferromagnesian minerals and elongation of quartz and feldspar. The gneiss weathers readily into angular slabs. The minerals are nearly the same as in typical granitic gneiss, but are weathered almost beyond recognition in most places. This gneiss gradually grades into more typical pink to bronze granite gneiss.

A major part of the crystalline rocks consists of migmatites formed by partial assimilation of hornblende gneiss and gabbroic gneiss by granite and related pegmatites (Fig. 5). All migmatitic gradations exist between typical granitic gneiss and hornblende gneiss or gabbroic gneiss. In some localities, such as near Eagle Peak, hornblende gneiss occurs as sharply defined xenoliths in the granitic gneiss (Fig. 6), whereas elsewhere it has been partly assimilated and drawn out into prominent schlieren, or has nearly disappeared as vague diffuse patches of hornblende crystals in the intrusive granitic gneiss. In places the usual leucogranitic gneiss has incorporated perhaps 30% of its volume as hornblende from the mechanical assimilation of gabbroic gneiss or hornblende gneiss.

The most common of these migmatites is a medium-gray granitic gneiss that is distinctly darker than typical granitic gneiss. Pink or light-brownish colors are much less common, unlike typical granitic gneiss. The grain size is one to two millimeters in most places, although locally in

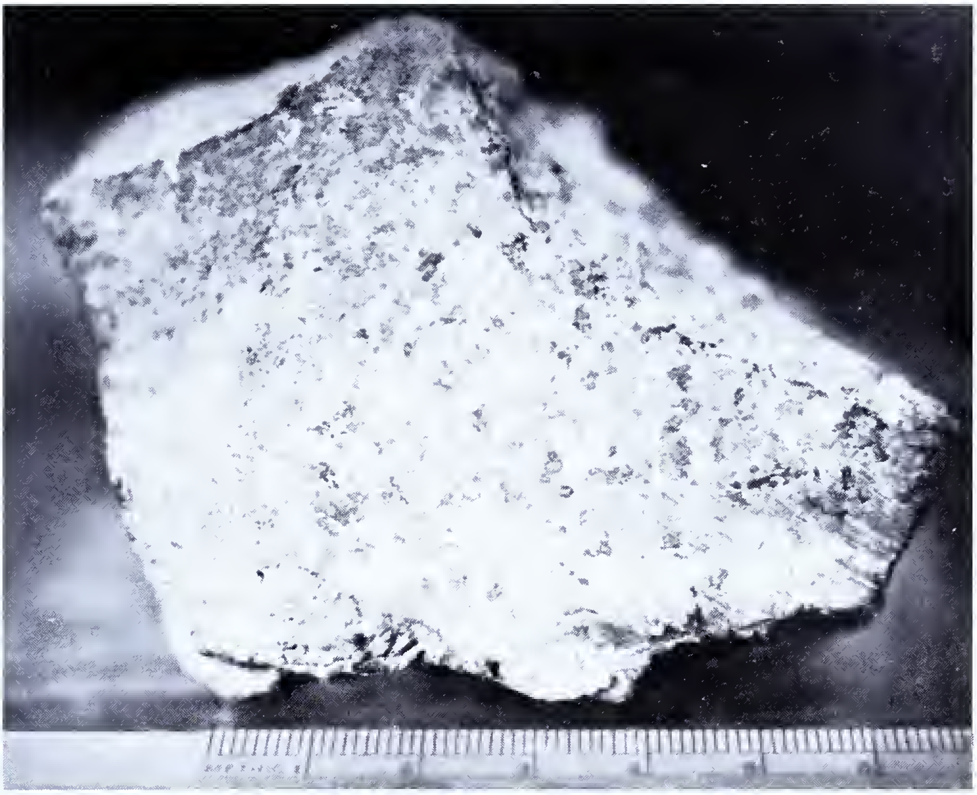


Figure 5. Migmatite formed by partial assimilation of hornblende gneiss by granite.

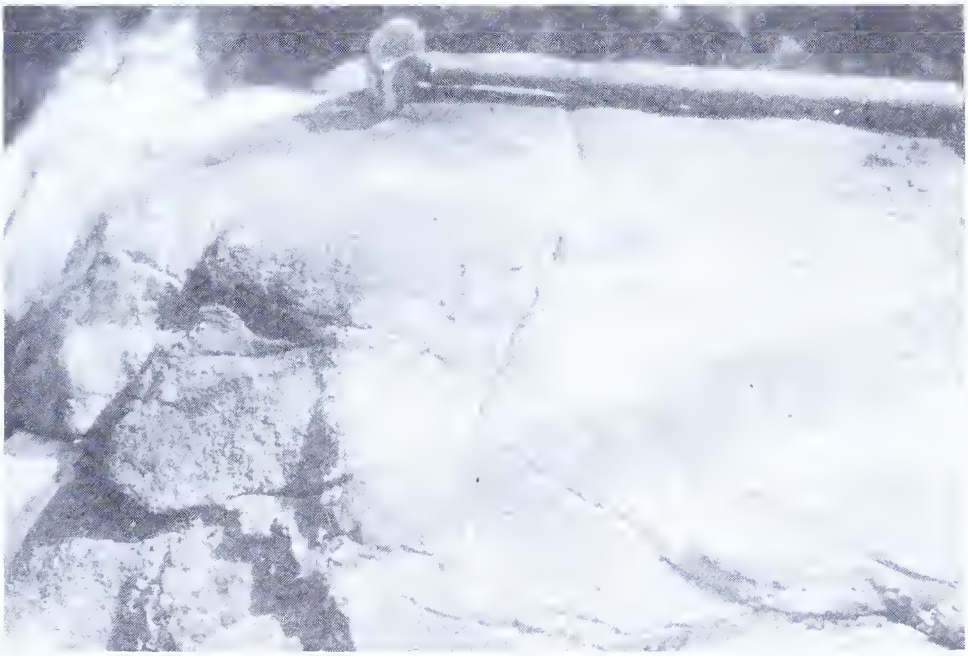


Figure 6. Xenoliths of hornblende gneiss in granitic gneiss.

areas of pegmatite, it is one centimeter. The minerals comprising it are almost the same as in ordinary granitic gneiss, but the proportions are different in that hornblende is far more abundant, ranging up to 30%. Also oligoclase is more abundant in the darker varieties than in typical granitic gneiss. The gneissic structure is much more prominent than in typical granitic gneiss. It is caused by alternate discontinuous bands and lenses of dark hornblende or minor biotite or hypersthene, separated by lighter bands of plagioclase, alkali feldspar and quartz. Many of the lenses are three to four inches long and about one-quarter inch apart, but the size and spacing are highly variable. Some lenses are ill-defined because of the chloritization of the ferromagnesian minerals and also because of the occurrence of isolated hornblende grains between the lenses. This gneiss in many places weathers slightly reddish and is found abundantly in the float in large angular to slightly rounded boulders.

A somewhat different migmatite containing granet is located at the extreme eastern edge of the quadrangle immediately north of the Triassic-crystalline contact and about one-half mile north of Laurel Ridge. It extends about one-half mile to the east into the adjoining Sinking Spring quadrangle where it is better exposed. This light- to medium-grayish-brown gneiss is somewhat pegmatitic and contains some grains a centimeter long, though most are one to six millimeters. It is composed of approximately 40% microcline and microcline perthite, 20% quartz, 15% oligoclase (An28), 10% orthoclase, 10% garnet and minor amounts of biotite, chlorite and accessories. Gneissic structure is quite evident as in most migmatites. The lack of definitely identifiable hornblende, the presence of garnet and biotite, and the nearness to known areas of graphitic gneiss, suggest this rock was formed by injection of a garnetiferous, graphitic gneiss rather than by injection of a hornblende gneiss. It is possible, though unlikely, that the garnet is of igneous origin, and the rock an unusual variant of granitic gneiss.

Correlation

The correlation of crystalline rocks between geographically separate areas is at best somewhat uncertain, even when the areas are relatively close. Under favorable conditions correlation of a crystalline rock formation can be approximated by several means; namely, similar ages obtained by geochronological methods, similar field relations to other rocks, similarity of mineral composition and texture, and continuity of exposures. No age dates have been obtained for the crystallines of South Mountain, but the other three methods are of aid in attempting to correlate the South Mountain rocks with the crystallines of the Reading Hills to the east in Berks, Lehigh and Northampton Counties and in the highlands of northern New Jersey.

Between South Mountain and the Reading Hills of Berks County, correlation of granitic gneiss is almost certain despite a six mile gap in outcrops, because the rocks are almost identical petrographically and the field relations with the other crystallines are the same. Farther east in Lehigh and Northampton Counties, the correlation is less certain, not only cause of the increasing distance, but also because the granitic gneiss, re termed the Byram and described by Fraser (1941) includes a somewhat der variety of rocks. The "pure" Byram which he describes, however, is ry similar to the granitic gneiss of South Mountain and again the field lations with the other crystallines appear the same, not only by mparison with the published reports but also by inspection in the field. several areas of northern New Jersey the crystallines have been mapped detail, and the light-colored acidic rocks considerably subdivided. On e basis of petrographic similarity and similar field relations, the anitic gneiss of South Mountain may correlate with the "hornblende anite gneiss" described by Sims (1958) in the Dover area and Hotz (1953) Ringwood. The hornblende content of the South Mountain granitic gneiss rather low, but the large amounts of microcline or microcline perthite d moderate amounts of relatively sodic plagioclase are similar. The anitic gneiss has little resemblence to the quartz-sodic plagioclase eisses of northern New Jersey such as the Losee gneiss (Hague, 1956), the bite-oligoclase granite of the Dover area (Sims, 1958), or the quartz-igoclase gneiss of Ringwood (Hotz, 1953), nor is it very much like the re narrowly defined "Byram gneiss" described by Hague (1956) in the anklin-Sterling area. In view of the distance from the New Jersey areas South Mountain, about 90 miles, the lack of detailed information on a rtion of the intervening areas, and the rather poor crystalline exposures South Mountain and the western part of the Reading Hills, the suggested rrelations are certainly tentative.

Origin

An origin characterized by replacement of hornblende gneiss by ranitizing" fluids has been previously described by the writer (1958) for milar rocks which are well exposed at Antietam Lake in the Reading adrangle. The chief evidence cited there is the orientation of hornblende eiss xenoliths in granitic gneiss similar to that of the hornblende gneiss untry rock. No outcrops in South Mountain show this relation, but veral large float boulders suggest similar relations (Fig. 6). In some oat boulders the xenoliths are replaced to the point where they are now ost-like streaks and patches of nearly assimilated hornblende gneiss.

On the whole, petrographic evidence in the South Mountain area is t very convincing of a granitized origin. However, Gorai (1951) has ggested that metamorphic twinning in plagioclase may indicate a anitized origin for rocks like the granitic gneiss. His studies show that anitic gneiss rocks of igneous origin usually show Carlsbad twinning and casionally the more complex twins, whereas granitic rocks of replacement migmatitic origin usually show metamorphic twinning, namely albite and ricline types. Further petrographic evidences of replacement origin, ntioned by Moorhouse (1959, pp. 278-9), and rather weak by themselves, but least locally applicable here, are the presence of a more or less ndescript mosaic texture, a considerable variation in grain size within e area of a thin section, and irregularity in texture and composition.

During the later stages or after granitization of hornblende gneiss the granitic gneiss was regionally metamorphosed as indicated by several textural features earlier referred to; namely, numerous sutured contacts, especially of quartz grains, microscopic crushed zones which have been partly recrystallized, mortar structure, weak elongation of quartz, and slight parallelism of hornblende and minor biotite. It is probable that this metamorphism superimposed on the newly granitized granitic gneiss did not go much beyond the low greenschist facies and that the widespread chlorite, sericite and epidote were developed at this time in addition to the textures above. If regional metamorphism did reach higher grades, than retrograde metamorphism apparently occurred, because chlorite, sericite and epidote, rather typical of low grade metamorphic conditions, are widespread

HORNBLENDE GNEISS

Distribution

Hornblende gneiss is the second most abundant of the Precambrian formations. A few rather small patches occur in the western part of South Mountain near Womelsdorf Mountain and in the southeastern part of the mountain, but usually it has been so extensively intruded and partly assimilated by granite that it cannot be mapped separately. Almost half of the area of South Mountain is mapped as migmatites which have resulted from the invasion of hornblende gneiss by granite.

Petrography

The rocks mapped as hornblende gneiss comprise two chief varieties, an abundant, well-foliated hornblende gneiss and a much less common gabbroic gneiss. These rocks are mineralogically similar, but differ considerably in texture. Because of the close association of the two types in float, they have not been mapped separately.

Gabbroic gneiss is a very dark-gray to nearly black rock, which locally has a "salt and pepper" appearance (Fig. 7) resulting from contrasting black grains of ferromagnesian minerals among gray grains of plagioclase. Some of it is greenish black because of chloritization of the ferromagnesians. The grain size ranges from about 1 to 5 millimeters, and in a few gabbroic gneisses, hornblende is distinctly larger than plagioclas The rock is composed of about 50% labradorite or less commonly andesine, and 50% ferromagnesians, which include hornblende chiefly and clinopyroxene hypersthene, and minor biotite. The amount of hornblende and pyroxene is quite variable. Hornblende is almost always present and usually dominant, but in some gneisses pyroxene is most abundant. The pyroxenes may be present together or separately. Similar relations have been noted by Sims (1958) in the amphibolites of the Dover area of northern New Jersey. Quartz is uncommon except in the migmatites which have been injected by granitic material. In one gneiss it occurs as infrequent small anhedra

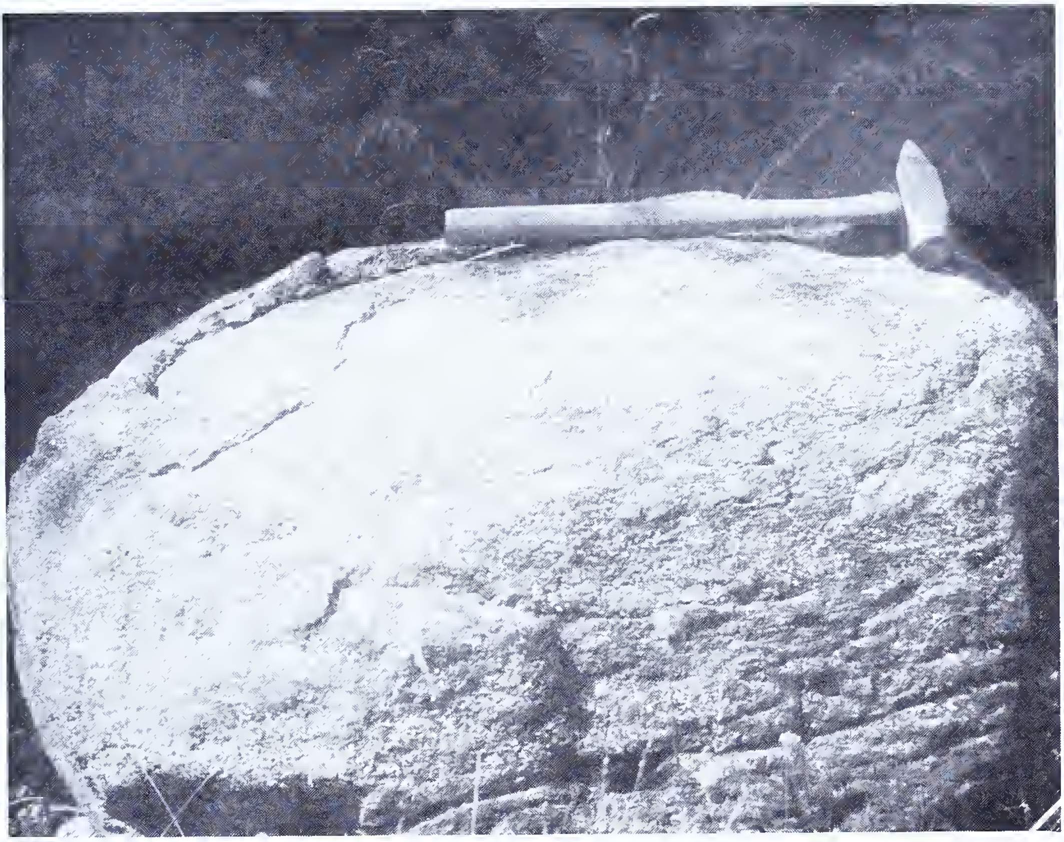


Figure 7. Gabbroic hornblende gneiss showing "salt and pepper" texture.

disseminated throughout the rock. The gneissic structure is weak in most gabbroic gneiss and is absent in some. That which is present is the result of parallel orientation of elongated ferromagnesian minerals. No banding was observed. Hornblende gneiss is dark gray to black with most grains about one to two millimeters in diameter. Hornblende is the predominant ferromagnesian mineral, though the same pyroxenes occur as in gabbroic gneiss. Occasionally a little biotite and red garnet are present. The chief distinction between hornblende gneiss and gabbroic gneiss is the much more evident foliation of hornblende gneiss and occasionally more abundant pyroxene in gabbroic gneiss. The foliation is due to parallelism of hornblende and sometimes pyroxene grains. These are segregated in a few places into even discontinuous bands separated by bands of predominantly plagioclase. All varieties exist between typical hornblende gneiss and typical gabbroic gneiss.

In both types of gneiss, hornblende usually exhibits pleochroism from pale yellow brown to dark brown. However, in one gneiss moderately invaded by granitic material, hornblende is light greenish brown to deep greenish brown. In another gneiss with little hornblende and abundant pyroxene, hornblende is pale green to medium green similar to the hornblende of granitic gneiss. The optic angle of the common brown hornblende is visually estimated at about 70° and the maximum observed extinction angle between the C axis and the slow ray is 23°. Biotite, which is rather uncommon, is usually pleochroic from pale yellow brown to deep brown. It occurs generally as elongate crystals somewhat embayed by quartz and feldspar. The ends of the crystals are frequently embayed and frayed. The clinopyroxene is largely pale green augite with a maximum extinction angle, C axis to slow ray, of 54°. However, it closely resembles diopside and the bulk of the elongate sections have extinction angles within the diopside range (34°- 44°). A small amount of diallage, with very conspicuous parting, is locally present. The orthopyroxene is pale pinkish hypersthene, frequently showing some color contrast to the greenish clinopyroxene. The pyroxenes are almost entirely andhedral, though a few are subhedral and elongated. They usually exhibit a mosiac texture with the other minerals. A few clinopyroxene grains are poikilitically enclosed within hornblende and a very few crystals of clinopyroxene occur as cores within hornblende suggesting hornblende is later than pyroxene. Most pyroxene is andhedral and shows no evident replacing relationships with either hornblende or the other minerals. The texture of both varieties is largely crystalloblastic and very little of the original crystal shape is preserved in the rocks at the facies of metmorphism now exhibited.

Field Relations

The field relations of gabbroic gneiss and hornblende gneiss with granitic gneiss are discussed mainly in the section on granitic gneiss and also in the section on quartz diorite gneiss.

In most localities where graphitic gneiss is abundant, hornblende gneiss occurs associated with it in the float. Separation of the two rock types along contacts is impossible in most places. The exact structural relations are not clear in this area because the two formations have not yet been found together in an outcrop. However, at one locality about a mile east of Pleasant Retreat School on the Wernersville road near Waldesruh Farm, graphitic gneiss underlies concordantly a gneiss which is about intermediate in composition between hornblende gneiss and graphitic gneiss. True hornblende gneiss occurs in float in the immediate vicinity but does not crop out. A similar intermediate type of gneiss occurs in graphitic gneiss and hornblende gneiss float near the intersection of the Blainsport-Newmanstown-Cocalico roads.

Origin

The hornblende gneiss variety appears to be in part of sedimentary origin. On South Mountain alone the best evidence is the interbedding of graphitic gneiss of nearly certain sedimentary origin with gneisses intermediate in composition between hornblende gneiss and graphitic gneiss. In the nearby Reading Hills the evidence is stronger because the hornblende gneiss is not only interbedded but also grades into graphitic gneiss. Such interbedding may suggest metamorphosed sills or flows of perhaps diabase or basalt, but this appears unlikely in view of the gradational transition zone between hornblende gneiss and the metasediments. The intermediate gneisses may well represent sediments of composition between the carbonaceous sediments that resulted in graphitic gneiss and the impure calcareous sediments that resulted in hornblende gneiss. The minor quartz which is disseminated throughout hornblende gneiss at one locality may represent original quartz sand grains.

The origin of the gabbroic gneiss is considerably more uncertain than that of hornblende gneiss. In view of the gradation of gabbroic gneiss into the more typical hornblende gneiss and the fact that mineralogically they are quite similar, it is possible that the gabbroic gneiss is also of sedimentary origin. The chief difference between them is the considerably weaker gneissic structure of the gabbroic gneiss. Field relations do not indicate very clearly either an igneous or sedimentary origin for the gabbroic gneiss and indeed this gneiss is very poorly exposed. Megascopically its lack of gneissic structure imparts superficially an igneous appearance, but microscopically the crystalloblastic amd mosiac texture gives little indication of a former igneous origin. Few of the crystals are subhedral and little evidence is present for typical igneous textures such as porphyritic, diabasic or hypidiomorphic.

The mineralogy of both gneisses suggests they have been regionally metamorphosed approximately to the sillimanite-almandite subfacies of the amphibolite facies. At approximately this facies the color of hornblende changes from greens to browns (Miyashiro, 1961) as it is in most of these gneisses. Amphibolites very similar to these and at about the same stage of metamorphism have been described by Sims (1958, p. 25) in the Dover area of northern New Jersey and for somewhat similar reasons have been considered to be of questionable metasedimentary origin.

With some metamorphic rocks that have not undergone metasomatism, an estimate of the original source may be made from their bulk chemical composition. This is not very feasible with hornblende gneiss because a variety of rocks with similar compositions but different origins may give rise ultimately to hornblende gneiss as a result of regional metamorphism. Thus some tuffs, basalts, gabbros, and certain calcareous, iron bearing sediments, like limy shales, all may converge on metamorphism to give rise to hornblende gneiss. Occasionally the composition of a rock may be fairly well calculated by use of the optical properties of the constituent minerals. This method of determining bulk chemical composition is not very useful with hornblende gneiss because of the difficulty of correlating the optical properties of hornblende with its complex chemical composition. Friedman (1960, p. 73) has commented on the problems of this type of correlation including those of the amphiboles.

GRAPHITIC GNEISS

Distribution

Graphitic gneiss and related rocks occur in two principal areas in South Mountain. The first comprises several small patches of float near the hearwaters of Furnace Creek and the other an area about a mile long and half a mile wide a short distance north of Laurel Ridge. Float pieces occur elsewhere, but in insufficient quantity to map separately.

Petrography

Three related gneisses make up the bulk of the formation. The mos common is a cream-colored or light- to medium-gray gneiss which, in a few places, shows a pinkish cast. Most of the grains are about one-half millimeter in diameter and only a few are as large as one millimeter. On weathering, the feldspars usually become a dull white and the ferromagnesi minerals limonitic, so that the rock has a speckled brown and white appearance. The minerals include quartz, orthoclase, microcline, plagiocl (chiefly andesine), some graphite, biotite, pyroxene, and infrequently granet. The relative amount of potash and plagioclase feldspar is variabl In most gneisses potash feldspar exceeds plagioclase, but in a few, potash feldspar is lacking. Hematite and apatite are accessories. The commonest pyroxene is hypersthene, and less abundant is augite. The ferromagnesian minerals are chloritized in many places. Graphite occurs in flakes one t two millimeters in diameter, somewhat larger than the usual grain of the rock, and disseminated throughout the gneiss. It rarely occurs in short, thin bands. Graphite occurs sparingly at nearly all places. At only one locality, an outcrop in the area north of Laurel Ridge, was the graphite content as high as an estimated 10%. The mineral here had a brilliant, glistening, tin-white, metallic luster which is a helpful aid in identification of this gneiss. The gneissic structure is more evident than in granite gneiss, but is less obvious than in hornblende gneiss. It is due to parallelism of the ferromagnesians and granphite, and to a slight elongation of quartz and feldspar crystals.

Another abundant variety is a very light-buff, coarser-grained migmatitic gneiss that has resulted from injection by granite and related pegmatites into the graphitic gneiss. Granitic seams and veins intruded parallel to the gneissic structure are abundant. Locally pegmatitic injection and "soaking" has been so intense that little is left megascopic to indicate graphitic gneiss except a little graphite. On weathering it shows the same speakled and blotchy brown and white appearance as the fine grained variety. The grains range in size from one-half to six millimeter and the texture is irregular. The minerals are essentially the same as in the finer variety, except that the ferromagnesian minerals and graphite ar less abundant, and potash feldspars are more abundant. The extra potash feldspar has apparently come from intrusion by the granitic and pegmatitic solutions which formed almost certainly at a higher temperature than the graphitic gneiss itself. The work of Tuttle and Bowen (1958) suggests tha uch solutions can form as low as about 600°C , which is probably at least 00° to 200° higher than the temperature of formation of graphitic gneiss hich has been subjected to moderate regional matamorphism. The gneissic tructure is much more evident than in the finer-grained variety and is the esult of parallelism of ferromagnesians and graphite and a more pronounced longation of quartz and feldspar grains. This megmatitic variety of raphitic gneiss and to a lesser extent the finer-grained variety closely esemble leucogranite gneiss, especially since graphite is by no means resent at all localities. As injection and permeation by granitic "juices" ncreased, the resulting migmatite resembles more and more a pegmatitic ranite gneiss. The following criteria, published in an earlier report by he writer (1959) help to distinguish graphitic gneiss from granite gneiss:

Graphitic gneiss	Granite gneiss
Usually low in ferromagnesians except biotite.	1. Usually some ferromagnesians, particularly hornblende and its alteration product, chlorite.
Usually strong elongation of quartz and feldspar crystals.	2. Generally weak quartz-feldspar elongation.
Some varieties are very fine grained (0.5mm and less).	3. Usually medium-coarse grained (1 to 5mm).
Some float pieces weather fairly soft. Broken without difficulty.	4. Mostly hard resistant float.
Usually weathers light buff to white.	5. Weathers buff or gray.
Fairly evident gneissic structure.	6. Usually weak gneissic structure.
Tends to weather into small slab-like pieces.	7. Tends to weather into knobby, larger, rounded boulders.
Associated in places with gneiss intermediate in composition between hornblende gneiss and typical graphitic gneiss.	8. Usually associated with hornblende gneiss.

A third, much less abundant variety is a fine-grained, medium- to ark-gray gneiss which in places shows a bluish to bluish-gray cast. It ccurs mainly at and near the outcrops in the graphitic gneiss area ocated north of Laurel Ridge. It contains chiefly plagioclase (andesine to abradorite), and pyroxene, predominantly hypersthene. Garnet, biotite, ornblende, and graphite occur in lesser amounts, and rarely orthoclase and icrocline are present. It is intermediate in composition between hornblende gneiss and graphitic gneiss. Graphite is very sparing and the darker phase of this rock may be confused easily with either hornblende gneiss, quartz diorite gneiss or even the coarser phases of metadiabase. Locally float pieces show a hard, buff, outer weathered zone about a half-inch thick and an inner blue-gray core.

Origin

Graphitic gneiss is probably of metasedimentary origin and, in view of its present mineral composition, was apparently formed by regional metamorphism of a carbonaceous sandstone to approximately the sillimanite-almandite subfacies of the amphibolite facies. Graphite is usually considered an indicator of metamorphism of carbonaceous sediments (Heinrich, 1956, p. 223). The occurrence of biotite as the most abundant ferromagnesian mineral and the occasional presence of garnet also lends support to the sedimentary origin. Near Boyertown, in the Reading Hills, some good quarry exposures and abundant float strongly suggest that graphitic gneiss, almost identical to that of South Mountain, is interbedde with marble, termed Franklin "limestone". As the marble is of certain metasedimentary origin, the interbedded graphitic gneiss would probably als then be metasedimentary. Quartz-graphite-feldspar gneisses of Lehigh and Northampton Counties (Fraser, 1941, p. 144-146),which are similar to the graphitic gneiss, are also intimately associated with marble. Microscopically the graphitic gneiss shows no indication of former igneous textures. Finally a graphitic gneiss from the Reading Hills similar to those of South Mountain contains two varieties of plagioclase, which is explicable only by a sedimentary origin.

QUARTZ DIORITE GNEISS

Distribution and Name

This gneiss is least common of all the Precambrian rocks and occurs only in three areas large enough to be mapped. All are in the northwestern part of South Mountain, near Furnace Creek. The chief locality is a small, apparently slumped outcrop along the Blainsport-Newmanstown road, approximately one-half mile east of the intersection of this road with the Cocalico road.

This rock was formerly termed the Furnace Creek quartz diorite gnei from the above locality by the writer in an earlier paper (1953). The value of assigning formation names to certain crystalline rocks is rather doubtful, particularly because their origin, age, and correlation usually are not clear. As mentioned later, the quartz diorite gneiss appears to be a special sort of migmatite of rather variable composition rather than a bona-fide igneous rock, and hence it does not merit a formational name more than other migmatites of the Reading area. The current practice, describe before, in crystalline rock areas tends to assign specific lithologic names ather than formational names. These names give a better indication of the ineral composition of the rock, which is one of the chief factors useful n correlation, and they also avoid a needless assemblage of formation ames of uncertain value.

Petrography

The quartz diorite gneiss is generally a dark-greenish-gray to dark-ray rock with a grain size ranging from one-half to three millimeters in iameter. It resembles the common anorthosites of the Adirondacks. As it rades into hornblende gneiss it becomes very dark gray to nearly black. t contains about 25% quartz, 50% andesine (An31-37), and the remainder is ugite, hypersthene, hornblende, and biotite. In places over 10% of otash feldspar is present, hence the rock should then be termed granoiorite. Augite is usually fresh and relatively uncorroded, but ypersthene is largely altered to a mixed aggregate, in part sericitic. ericite contains potassium, hydroxyl, and aluminum ions which are not ound in hypersthene, hence some introduction of these ions is evident. e granitic material which helped form the quartz diorite gneiss as iscussed below was probably the agent which brought in these ions.

The gneissic structure is less well-developed than in hornblende eiss (Fig. 8), but is usually more evident than in granite gneiss or

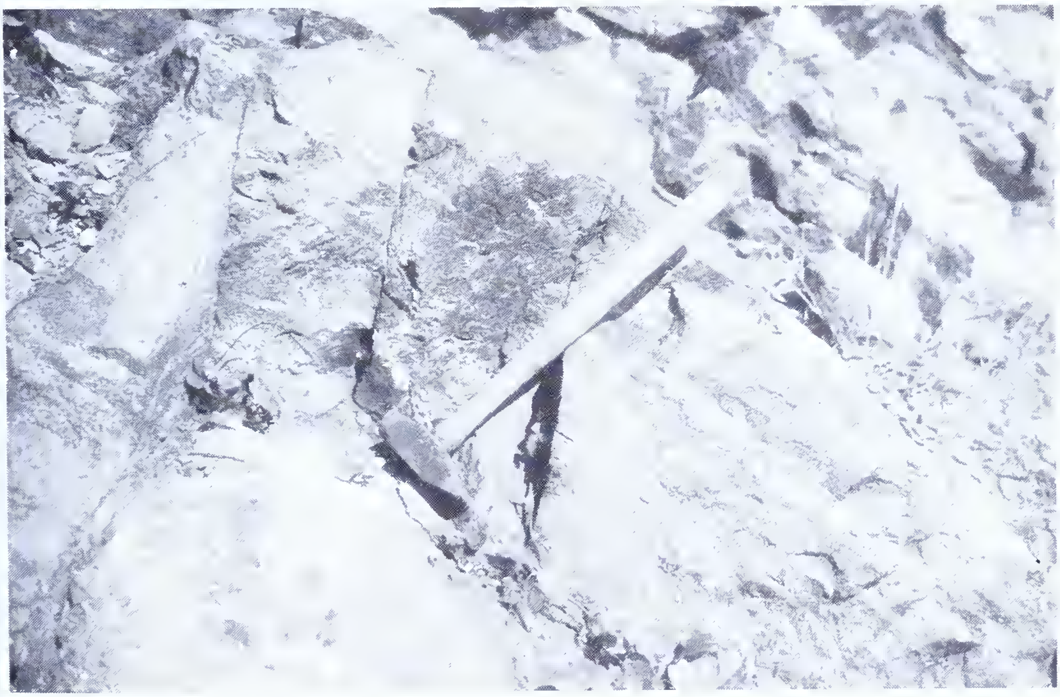


Figure 8. Weak gneissic structure of quartz diorite gneiss.

gabbroic gneiss. In some localities the gneissic structure is the result of separation of bands of dark ferromagnesian minerals about one-sixteenth to one-eighth inch apart. The dark bands are usually not much over an inch long and not well-defined though in a few places they are fairly conspicuous (Fig. 9). The lighter bands contain greenish-gray quartz, plagioclase, and a little disseminated hornblende. In other places the light bands are very short and ill-defined, and the gneissic structure is the result of a slight elongation of quartz and feldspar and parallelism of hornblende and biotite.

Field Relations and Origin

All the small areas of quartz diorite gneiss, including the unmapp minor occurrences, grade imperceptibly into either granite gneiss, hornble gneiss, or into the common migmatites of the latter, which are formed by simple, partial mechanical assimilation of hornblende gneiss by granite gneiss. In a few places quartz diorite itself contains diffuse bands and clots of hornblende, but usually it is a homogeneous rock.

Quartz diorite, however, falls mineralogically between granite gneiss and hornblende gneiss, and appears to represent local masses of granitic magma that had completely or almost completely assimilated hornblende gneiss. The nearly homogeneous fluid magma then crystallized, but with a more basic composition. In a sense this quartz diorite is only an unusual migmatitic variant of granite gneiss, but its different mineralogy and field appearance justified mapping it separately. Somewhat similar processes are believed by Fraser (1941, pp. 159-160) to have formed certain migmatitic gneisses in Lehigh County of composition intermediate between granite and diorite gneiss.

PEGMATITES

Distribution and Structure

Pegmatite and associated aplite are widely distributed throughout South Mountain, but are quantitatively relatively unimportant. Most pegmatites occur as dikes a few inches to a few feet in width. Few dikes are as wide as eight feet and only two are known to have contained commercial quantities of muscovite. The latter are in Lancaster County o the south side of the mountain within the area of pegmatitic granite gneis Although outcrops are so uncommon that exact structural relations are difficult to determine, pegmatites appear to cut all the Precambrian formations except metadiabase. Most of them are found in granite gneiss, into which they grade. One of the larger ones on the south slope of Sout Mountain shows zoning with a core of quartz and muscovite and an outer zo of pink microcline, perthite, and a little biotite.

Petrography

All the pegmatites observed, including the formerly commercial ones, ave a simple mineralogy; all can be put in the "simple" class defined by andes (1933). The color ranges from white to brown, depending on the uantity of weathered ferromagnesians. The grain size is variable as may e expected with pegmatites. It ranges from one millimeter in the aplites o several inches in the commercial pegmatites. The common minerals are uartz, microcline, including perthite, sodic plagioclase, orthoclase, iotite, and muscovite. Microcline is ever-present, sodic plagioclase less bundant, and orthoclase relatively uncommon. Some pegmatites, particularly hose occurring as thin lenses in the granite gneiss, show a distinct neissic structure due to a pronounced elongation of quartz and feldspar rains. This structure appears to have been superimposed on the original, eterogeneous pegmatitic texture.

METADIABASE

Distribution

Metadiabase dikes are numerous on South Mountain. Some, represented y float, are traceable only over one or two hundred feet and are but a ew feet wide at most. The largest, which trends northeastwardly in the icinity of Furnace Creek, is at least $1\frac{1}{4}$ miles long and at least 100 feet ide. None of the dikes crop out.

Petrography

Metadiabase is dark-greenish-gray to almost black when fresh, and eathers medium gray to brown. It is tough and resistant to weathering and n places forms float boulders locally known as "ironstone", which ring hen struck by a hammer. The grain size is about one-half to one millimeter. he typical disbasic texture, characterized by euhedral to subhedral lagioclase in a matrix of anhedral to subhedral pyroxene, is almost verywhere present. Under the microscope, augite comprises about 25 to 40%, agnetite 5 to 10%, and labradorite or andesine 40 to 60% of the rock.

Augite is usually neutral to very pale brown, in one place with a light pinkish-brown cast. Weakly developed polysynthetic twins with (001) s the twin plane were noted in one diabase and a few grains show twins ith (100) as the twin plane. It is usually partly altered to greenish hlorite and some epidote. Green hornblende locally replaces augite, mostly long the edges of the crystals. Biotite usually occurs as a few tiny hred-like crystals. In one diabase it appears to replace hornblende, in nother augite. It is altered in part to green chlorite. Orthopyroxene as not observed, though some of the diabase is so thoroughly altered that he residual pyroxene is very difficult to identify. All the plagioclase, anges in composition between An41 and An56 except in one dike where it is An35. Plagioclase is usually considerably sericitized and is in many places altered to a confused saussuritic aggregate. Megnetite is frequently euhedral, but often also subhedral to anhedral. Infrequently i shows skeletal crystals. Ilmenite occurs sparingly. It is often indicate by leucoxene, which appears whitish in reflected light. It occurs infrequently as thin, band-like intergrowths in megnetite. A slight amoun of hematite staining is occasionally present. Quartz, apatite, and pyrite are accessory minerals. Quartz occurs as minute anhedral and also in rare micrographic intergrowths with feldspar. Apatite frequently occurs as elongate, nearly euhedral crystals and pyrite as anhedral grains in some places associated with magnetite.

Age

The age of the dikes cannot be accurately established as they cut no rock younger than Precambrian. All are petrographically similar both to the Precambrian dikes and to a post-Hardyston, pre-Triassic dike which occurs in the Reading-Boyerstown hills. However, as only one post-Hardyston, pre-Triassic dike is definitely known in that entire area, it i possible that most of the dikes of South Mountain are Precambrian. They are distinctly not Triassic as dikes of this age are much less altered than the older dikes. Plagioclase in Triassic dikes is usually relatively clear, in strong contrast to the saussuritic aggregates of the older dikes Alteration of augite to chlorite and epidote is much less common in the Triassic dikes than in the older ones.

HARDYSTON FORMATION

DISTRIBUTION

The Hardyston Formation forms the high ridges at the north and wes borders of South Mountain and also two small areas along the south side of the mountain near the east edge of the quadrangle. The highest point in the quadrangle, nearly 1400 feet, along the west border ridge, is underlai by this formation. In the western part of South Mountain the gneiss hills are about 100 feet lower than the Hardyston ridge. However, along the northeastern border of the mountain, the gneiss rises several hundred feet above the strongly sheared and faulted ridge of Hardyston.

STRATIGRAPHY AND PETROGRAPHY

At all exposures except the small southeastern ones, the lower 20 feet of the formation is a light-gray to dark-gray, coarse, quartz-pebble conglomerate. The beds are massive, averaging one to three feet in thickness. The pebbles and granules are rounded to subrounded, generally lorless to white, and range widely in size from about two millimeters to ree centimeters. The pebbles are quartz although locally as many as 20% e pink and white feldspar. Some of the quartz pebbles show undulose tinction under the microscope, suggesting a metamorphic source as in the anitic gneiss. The ratio of pebbles to matrix is variable because locally arse abundant pebble zones disappear laterally in a few tens of feet. e matrix is pink to gray, medium to coarse-grained, arkosic sandstone. crocline is the dominant feldspar, although orthoclase and plagioclase so occur. Occasionally sericite and limonite fill the interstices tween the grains. A small amount of conglomerate is medium to dark gray d contains enough chlorite and sericite in the matrix that it might be lled a conglomeratic graywacke. The conglomerate has been slightly gionally metamorphosed as is indicated by some sutured contacts between ains and distinct elongation of some of the pebbles. This metamorphism, wever, was not intense enough to convert overlying carbonate rocks to marble.

Most of the exposed formation above the basal conglomerate is made of a series of fine- to medium-grained, quartzitic sandstone and dimentary quartzite (Fig. 9). The usual color is light gray, but white,

Figure 9. Hardyston quartzite exposed in quarry of North American Refractory Brick Company on Eagle Peak.

light buff, dark gray, and blue gray are all present. The beds vary in thickness from an inch up to six feet. Most of them are about six inches to a foot thick. Some of the quartzite has a vitreous luster, so that individual grains are hard to distinguish, but in others clay from weathered feldspars results in a slightly earthy appearance. Feldspathic beds are common and apparently have little stratigraphic significance. Potash feldspar, both orthoclase and microcline, are more numerous than plagioclase. Feldspar is almost indistinguishable in hand specimen from quartz in some of the feldspathic quartzites, though readily apparent in thin section. Mild regional metamorphism is again indicated by some sutured contacts between grains and locally elongation of grains to as much as five to six times their width. Zircon and tourmaline are primary heavy detrital minerals. Worm tubes, earlier referred to as Scolithus linearis (Miller, 1941), have been found.

In the Reading Hills and in the eastern part of South Mountain, jasper is found in the uppermost part of the Hardyston, but it was not observed in this quadrangle. Its lithology and origin have been discussed particularly by Fraser (1937). Shale is likewise reported near the top of the Hardyston in Lehigh County (Miller, 1941, p. 170; Buckwalter, 1959) an in the Reading Hills (Wilkens, 1955), but none was noted in South Mountain

THICKNESS

A cross section (C-C' on Plate 1) based upon good exposures on Eagle Mountain indicates a thickness of about 600 feet. This section was made presuming the existence of a fault on Eagle Mountain; otherwise the thickness would be about 800 feet. In the Reading Hills the writer (1959) has estimated the thickness to be about 400 feet at Lobachsville, at the northeast end of Oley Valley, 250 feet near Bechtelsville on the eastern edge of the hills, and Miller (1941) estimated it to be about 250 feet in Lehigh County. No quarry or outcrop on South Mountain exposes more than 75 feet of the total thickness.

STRUCTURE

Nineteen outcrops of Precambrian gneisses were found on South Mountain on which the strike and dip of the foliation and rarely the lineation could be measured. A few of these were grouped closely together The readings from the outcrops in the fifteen separate areas serve to give a general picture of the Precambrian structure although details are lacking. The gneissic structure of all but one outcrop trends northeast to east and all but two dip southeast or south. The foliation appears to trend more toward the east in the eastern part of South Mountain. To some extent the shape of the hornblende-gneiss and graphitic-gneiss areas fit this trend. As most of these areas were mapped by float, and as they have been irregularly "soaked" and injected by granite and pegmatite, a precise conformity of their shape to the structural trends is probably not to be expected.

To some extent the foliation of the metasediments parallels that of granite gneiss, although the few outcrops do not give conclusive dence. A similar structural situation has been noted in northern Jersey (Sims, 1958; Hague, 1956) and the inference drawn that the nite was intruded as concordant sheets or phacoliths into the asediments. An alternate explanation is that much of the granite gneiss "granitized" metasediment, but specific evidence is weak on South ntain, as indicated in the section on granitic gneiss. One large float lder a mile southeast of Eagle Peak (Fig. 6) strongly indicates oriented oliths of hornblende gneiss, such as might be expected in a granitized a. Better evidence of such structures favoring a granitization erpretation is found at Antietam Lake in the Reading Hills (Buckwalter, 8).

The outstanding Paleozoic structural feature of South Mountain is major uplift which has exposed the Precambrian core flanked by eozoic sediments on the north and west and by down-faulted Triassic ks to the south. This major structure forms the westernmost part of Reading Prong, the southern extension of the New England Province, ch continues across southeastern Pennsylvania into northern New Jersey, theastern New York and western New England. The uplift here appears to sist largely of a great plate of crystalline rocks, Hardyston Formation minor carbonate rocks thrust over the carbonate rocks which form part the Great Valley. On the north side of South Mountain, both in this drangle and in the Sinking Spring quadrangle adjoining to the east, ndant field evidence of thrusting is present. One half mile south of esonia, for example, the crystalline rocks of South Mountain directly rlie the carbonate rocks of the Great Valley. In the Sinking Spring drangle, south of Wernersville and about a mile east of the Womelsdorf drangle, the crystallines are also thrust over carbonates for a distance about a mile along the mountain front. Here both the Hardyston and stallines are exceedingly sheared, in places being nearly mylonitized. the northwest and west side of South Mountain the Hardyston shows tle sign of shearing and it appears the edge of the thrust sheet lies ut three-fourths mile to the northwest in the Great Valley (see logic map and sections CC' & BB', Plate 1).

Magnetic data obtained from recent aeromagnetic surveys in south-tern Pennsylvania (Bromery and others, 1960) provide considerable dence for the existence of the thrust plate. The magnetic highs on th Mountain show a relief of only 150 gammas despite the fact that t of the mountain is made up of crystalline rocks which rise as much as feet above the Great Valley. This is in marked contrast to 1200-gammas ief on Mount Penn and other hills in the Reading Prong to the east, ch likewise are made up largely of crystalline rocks and which also have ut the same topographic relief as South Mountain. If the crystallines South Mountain continued at depth, the magnetic values should be much her than they actually are. The crystallines are evidently underlain at atively shallow depth by the carbonate sediments of the Great Valley.

Just south of the edge of the thrust sheet near Robesonia, along north border of South Mountain, the Hardyston is strongly overturned. ng the northwest and west flank of the mountain to the east of the main thrust, the Hardyston dips normally with a range of 27° to 52° to the northwest and west into the Great Valley, but very likely it is overturne at depth as suggested in cross-sections BB' & CC'. It seems improbable that relatively gentle folds would be associated with major thrusting, especially when the formations involved are clearly overturned only two miles away.

The largest fault on South Mountain other than the main thrust fault is a long northeast-trending normal fault (sections BB' & CC' and geologic map, Plate 1) which is believed to separate the two Hardyston ridges that form the mountain border south of the gap near Newmanstown Resevoir, about one mile southeast of Newmanstown. On Eagle Mountain thi fault is much less obvious, and is apparently displaced to the west by a tear fault. It probably extends as shown about a mile north of the gap, and is indicated topographically by a terrace-like feature on the west si of Eagle Mountain. A normal fault is not the only type of structure that could cause such a double ridge, but it seems most compatible with the general structural picture and the lack of shearing in this particular ar

Four transverse faults cut the Hardyston ridge on the north slope of South Mountain near Robesonia as shown on the geologic map. A similar but longer one, referred to above, cuts the western front. A small strea follows the strike of this fault.

The structures of the two small Hardyston areas in the southeaste part of the mountain are obscure. No lower Hardyston conglomerate crops out along their edges or is exposed as float. Possibly these structures are strongly sheared small synclines in which the lower conglomerate has been sheared out along the limbs and is thus not exposed. Similar structures are inferred on much better evidence in the Reading quadrangle

CARBONATE ROCKS

by

Alan R. Geyer

STRATIGRAPHY

The carbonate rocks of the Womelsdorf quadrangle range in age om Early Cambrian to Middle Cambrian. Quaternary colluvium deposits are esent over approximately half the area underlain by these carbonates,and e largely responsible for the lack of exposures of the bedrock in the lley.

In the carbonate rocks of the Great Valley, small exposures or ngle rock specimens are not sufficient to differentiate formations. It is ly after an extensive study of a great number of outcrops, that a compos- e section can be drawn and one formation distinguished from another. It indeed true that both the Cambrian and Ordovician limestones and dolomites cally contain similar looking rock types.

Cambrian System

Tomstown (Leithsville) Formation

The oldest formation of the carbonate sequence in the Womelsdorf adrangle is nearly completely covered by colluvium; little is known ncerning the detail of its lithology. Stose (1906) gave the name nstown to the dolomite sequence which overlies the Antietam quartzite in nklin County. This name was extended to the Reading area in later work ose and Jonas, 1935). The dolomite sequence lying immediately above Hardyston quartzite along the Delaware River was named Leithsville by rry (1909).

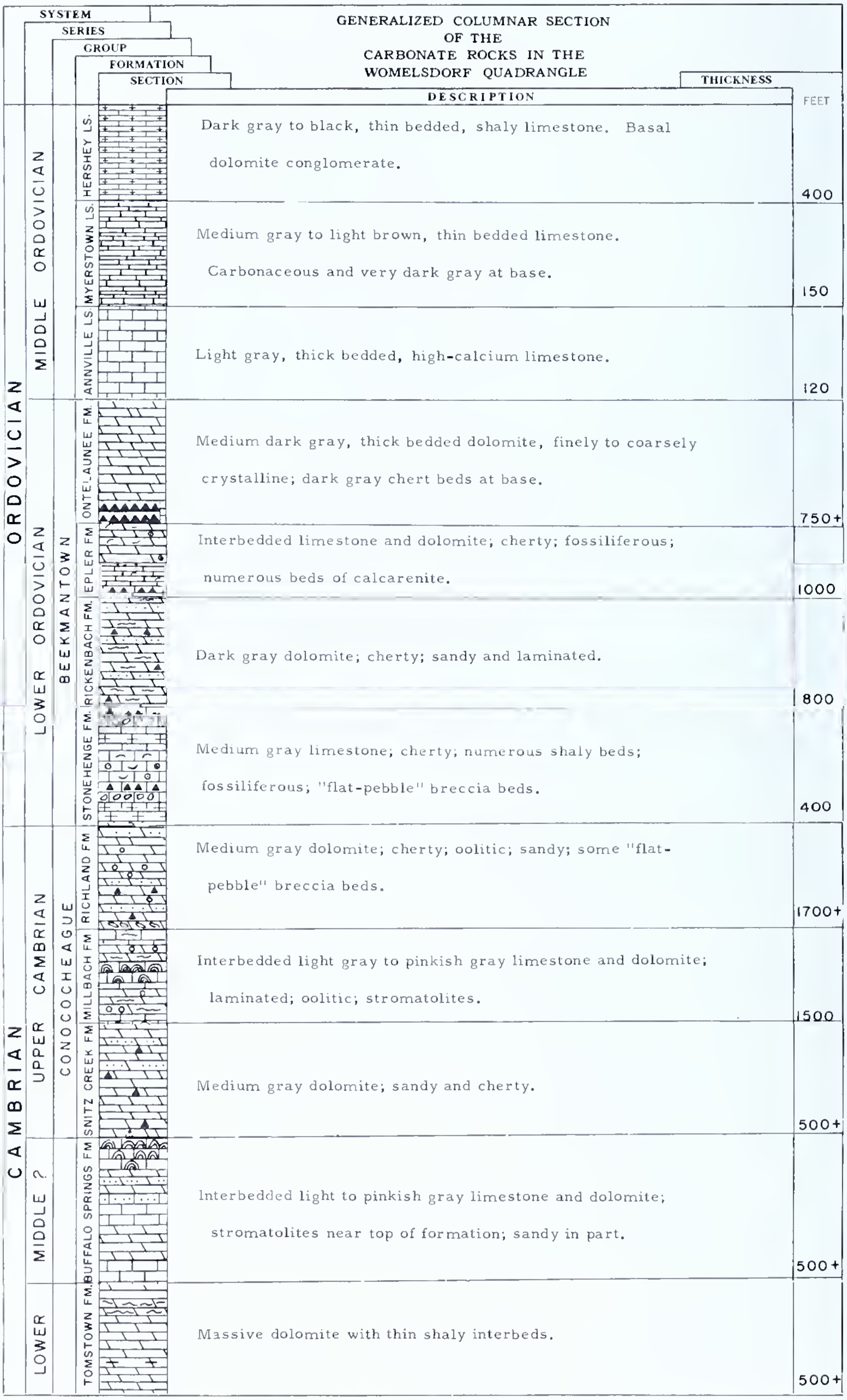
Approximately one and a half miles east of Kleinfeltersville, re is a small quarry in this formation. It is from this one good posure and isolated float fragments that the following description of the stown is made.

The base and lower part of this formation are composed of dium-light-gray to pinkish-gray, finely crystalline, sandy dolomite. all, isolated, well-rounded grains of clear quartz are common. These ains are easily seen on a weathered surface.

The upper part is medium-dark-gray to dark-gray, medium to fine- l crystalline dolomite. Thin beds of oolitic limestone occur in this rt of the formation. The dolomite is commonly platy bedded and finely minated.

The Tomstown has been involved in the complex structural move- nts of this area and because of the brittle nature of the rock, has been tensely fractured and impregnated with quartz to form an intricate net- rk of criss-crossing quartz veins in the dolomite.

Complicated structures and limited exposures make it impossible obtain a measurement of thickness.



GENERALIZED COLUMNAR SECTION OF THE CARBONATE ROCKS IN THE WOMELSDORF QUADRANGLE

SYSTEM	SERIES	GROUP	FORMATION	DESCRIPTION	THICKNESS FEET
ORDOVICIAN	MIDDLE ORDOVICIAN		HERSHEY LS.	Dark gray to black, thin bedded, shaly limestone. Basal dolomite conglomerate.	400
			MYERSTOWN LS.	Medium gray to light brown, thin bedded limestone. Carbonaceous and very dark gray at base.	150
			ANNVILLE LS.	Light gray, thick bedded, high-calcium limestone.	120
	LOWER ORDOVICIAN	BEEKMANTOWN	ONTELAUNEE FM.	Medium dark gray, thick bedded dolomite, finely to coarsely crystalline; dark gray chert beds at base.	750+
			EPLER FM	Interbedded limestone and dolomite; cherty; fossiliferous; numerous beds of calcarenite.	1000
			RICKENBACH FM.	Dark gray dolomite; cherty; sandy and laminated.	800
			STONEHENGE FM.	Medium gray limestone; cherty; numerous shaly beds; fossiliferous; "flat-pebble" breccia beds.	400
CAMBRIAN	UPPER CAMBRIAN	CONOCOCHEAGUE	RICHLAND FM	Medium gray dolomite; cherty; oolitic; sandy; some "flat-pebble" breccia beds.	1700+
			MILLBACH FM	Interbedded light gray to pinkish gray limestone and dolomite; laminated; oolitic; stromatolites.	1500
			SNITZ CREEK FM	Medium gray dolomite; sandy and cherty.	500+
	MIDDLE ?		BUFFALO SPRINGS FM	Interbedded light to pinkish gray limestone and dolomite; stromatolites near top of formation; sandy in part.	500+
	LOWER		TOMSTOWN FM.	Massive dolomite with thin shaly interbeds.	500+

Figure 10.

Buffalo Springs Formation

The Buffalo Springs Formation (Geyer and others, 1958), which has previously been considered to be the lowest member of the Conococheague Formation, is hereby separated from the Conococheague and raised to Formational status. This separation is based on the correlation of the overlying Snitz Creek Formation with the basal member of the Conococheague as described by Wilson (1952). The Buffalo Springs is also lithologically very similar to the Elbrook Limestone (Stose, 1906) and occupies approximately the same stratigraphic position.

Very few exposures of the base of the Buffalo Springs are present as a result of a thick cover of unconsolidated talus material.

The middle part of the formation is predominantly medium-gray, coarsely crystalline limestone with interbedded yellowish-gray, finely crystalline dolomite. White, milky, vein quartz is common.

The upper part is composed of light-yellowish-gray interbedded limestone and dolomite. Calcite veins and vugs occur throughout this portion of the formation.

A total thickness cannot be determined as neither the base nor the top are exposed. A minimum thickness of 500 feet is estimated from its width in outcrop. The Buffalo Springs Formation increases in thickness toward the west; from more than 700 feet in the Richland quadrangle to 800 - 1000 feet in the Lebanon quadrangle. A reference section is described (see Stratigraphic Sections - Locality 1.) in the Appendix.

Conococheague Group

Detailed mapping in the Womelsdorf quadrangle and adjacent quadrangles to the west has shown that major limestone and dolomite units can be separated from what was originally called the Conococheague Formation (Stose, 1908). In the adjacent Richland quadrangle (Gray and others, 1958) and in the Lebanon quadrangle (Geyer and others, 1958), the Conococheague was described as having five members. As stated above the lowest member has been removed from the Conococheague and established as an independent formation. The remaining four are here proposed as formations, and the original Conococheague Formation is raised to group status. Reference sections are described in the Appendix to illustrate the typical lithology of the three formations exposed in the Womelsdorf quadrangle.

Snitz Creek Formation

Directly overlying the Buffalo Springs Formation is the predominantly dolomite sequence of the Snitz Creek Formation.

The base of the Snitz Creek Formation is not exposed. Several exposures of the upper and middle parts show these sections to contain medium-light-gray to light-gray, coarsely crystalline, oolitic and cherty dolomite. Extremely coarsely crystalline dolomite is vuggy.

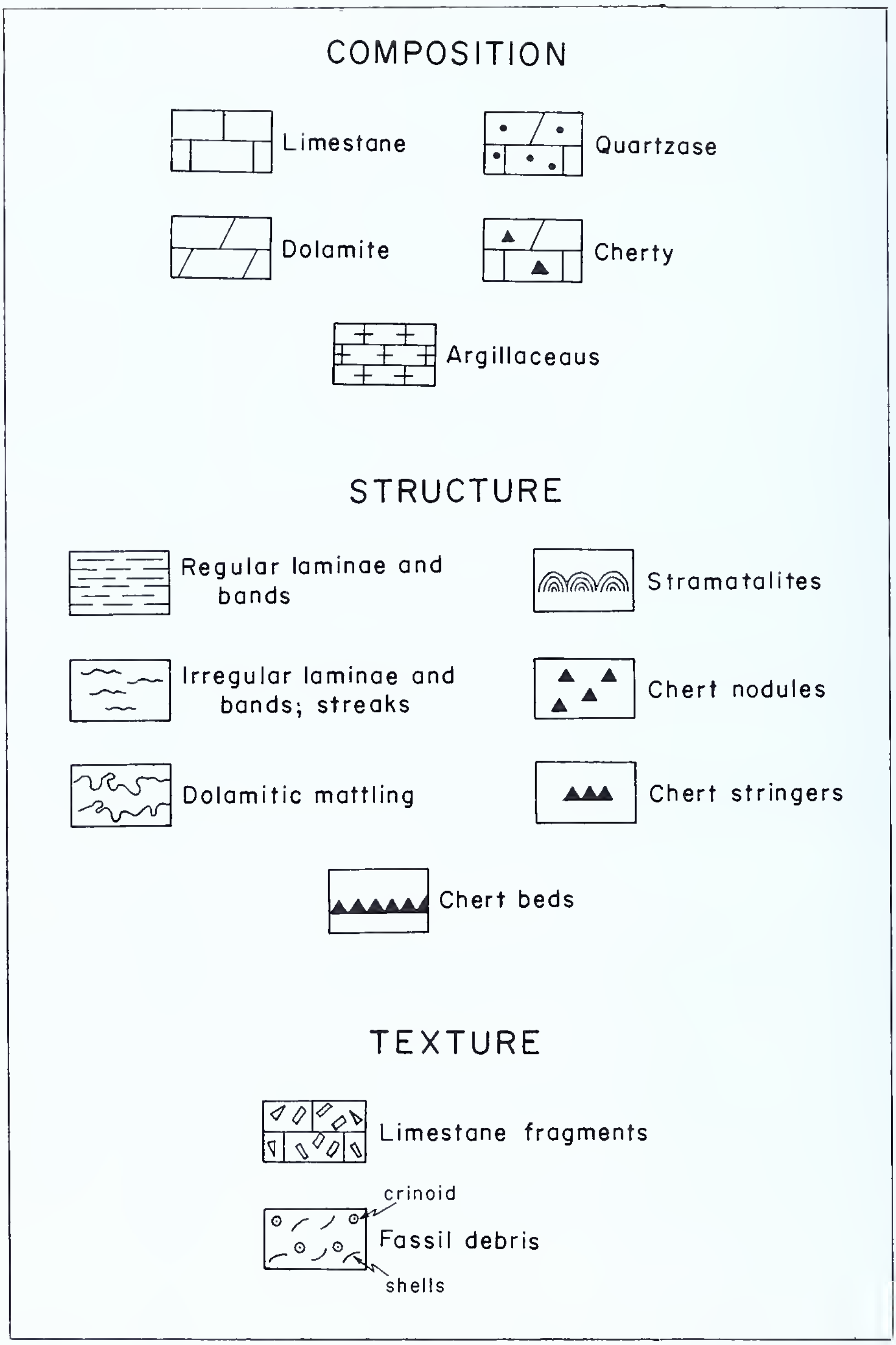


Figure 11. Symbols used for stratigraphic diagrams.

Sandstone beds, one foot to several feet thick, are present near the top. This sandstone is medium light gray on a fresh surface but weathers to a light- to moderate-brown color with complete removal of the dolomite cement. Dark-gray to grayish-black chert is found. A generalized composite section is illustrated in Figure 12.

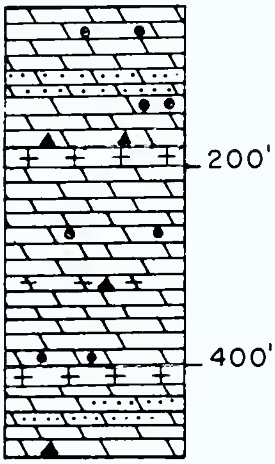


Figure 12. Generalized composite section of the Snitz Creek Formation, Womelsdorf quadrangle.

The rather abrupt change to quartz sediments coupled with the presence of "flat-pebble" breccias, oolites, and shaly interbeds are interpreted as indicating a major break in the sedimentation history of the carbonate sequence. As stated previously, the lithologic similarity of the Snitz Creek Formation to the basal member of the Conococheague Formation in its type area has led to the interpretation that this break is here properly the base of the Conococheague Group.

From detailed mapping in the Great Valley this formation has been found to increase in thickness from west to east; approximately 350 feet thick in the vicinity of Lebanon, Pennsylvania to more than 500 feet thick in the Womelsdorf quadrangle. A reference section is described in the Appendix (Locality 2.).

Millbach Formation

The Millbach Formation is a thick sequence of limestones and dolomites that stratigraphically overlies the Snitz Creek Formation in this quadrangle.

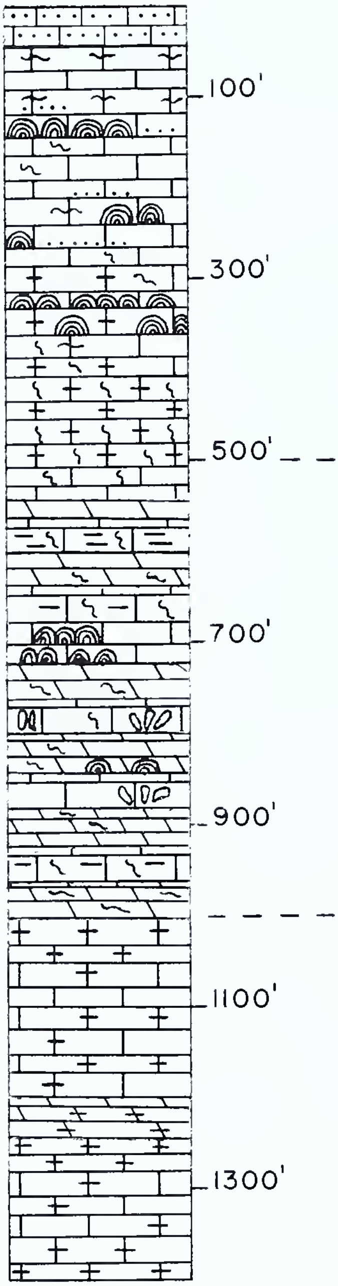


Figure 13. Generalized composite section of the Millbach Formation, Womelsdorf quadrangle.

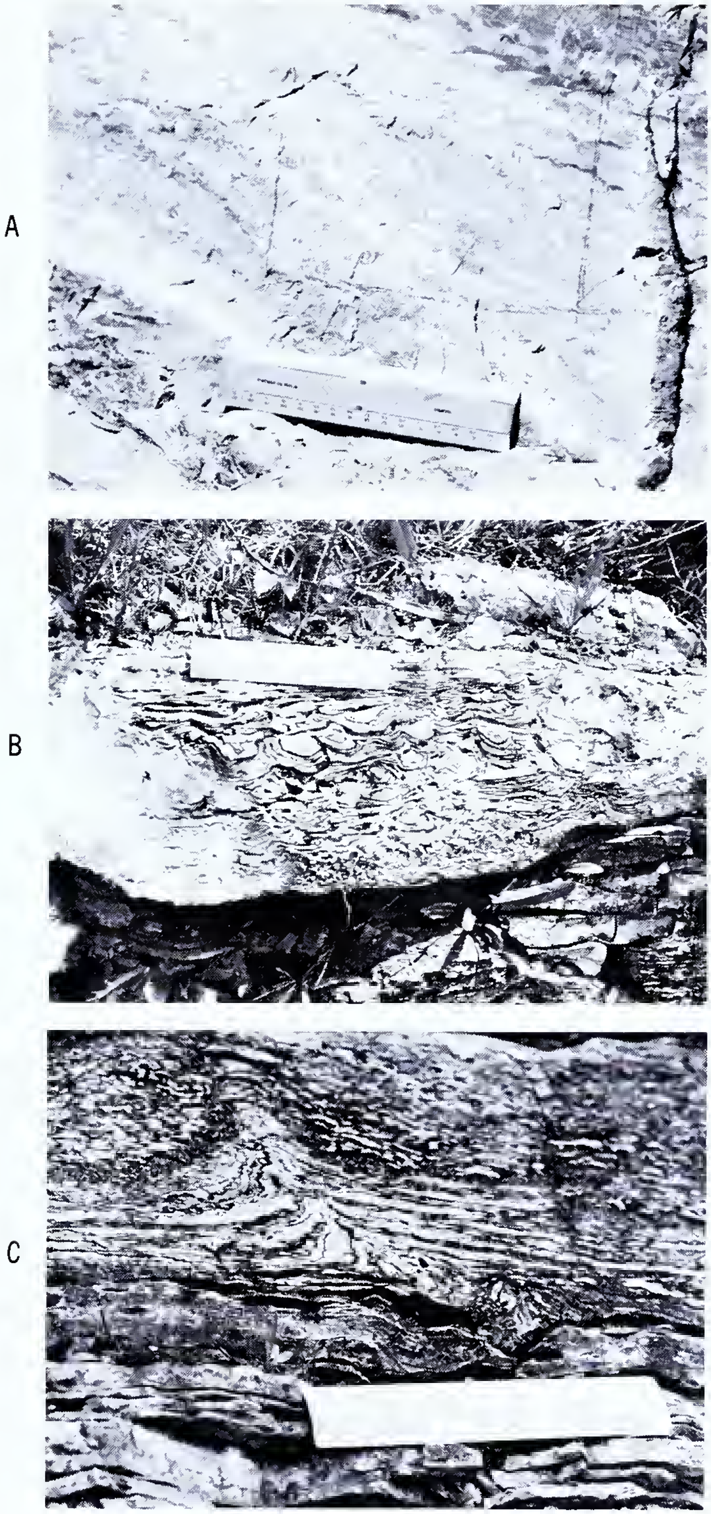


Figure 14. Stromatolites of the cryptozoon type in the Millbach Formation near Sheridan, Lebanon County.

The Millbach Formation is lithologically very similar to the Buffalo Springs and is distinguished from it principally by stratigraphic position. A composite section of the Millbach is shown in Figure 13.

The lower part is light-gray to white, medium-crystalline limestone containing medium-light-gray laminations.

The middle part is composed of light-gray to pink, finely crystalline limestones interbedded with pinkish, finely crystalline dolomite The color of the limestone ranges locally from pink to lavender to white. In the limestone, sandy beds up to one-half inch thick are present and stromatolites of the cryptozoon type and "flat-pebble" breccia beds are numerous. The dolomites also contain cryptozoon-type stromatolites.

The upper-most part of the formation is characterized by several feet of limonite-coated sandy limestone. The remainder of this upper part is light-gray to white, coarsely crystalline limestone. The lithology is interbedded with pinkish-gray, finely crystalline limestone. In places this latter lithotype shows fine shaly laminations. Bedding ranges in thickness from three inches to two feet and stromatolites are numerous. The top of the formation is located at the base of the first medium-gray, siliceous dolomite bed of the overlying Richland Formation.

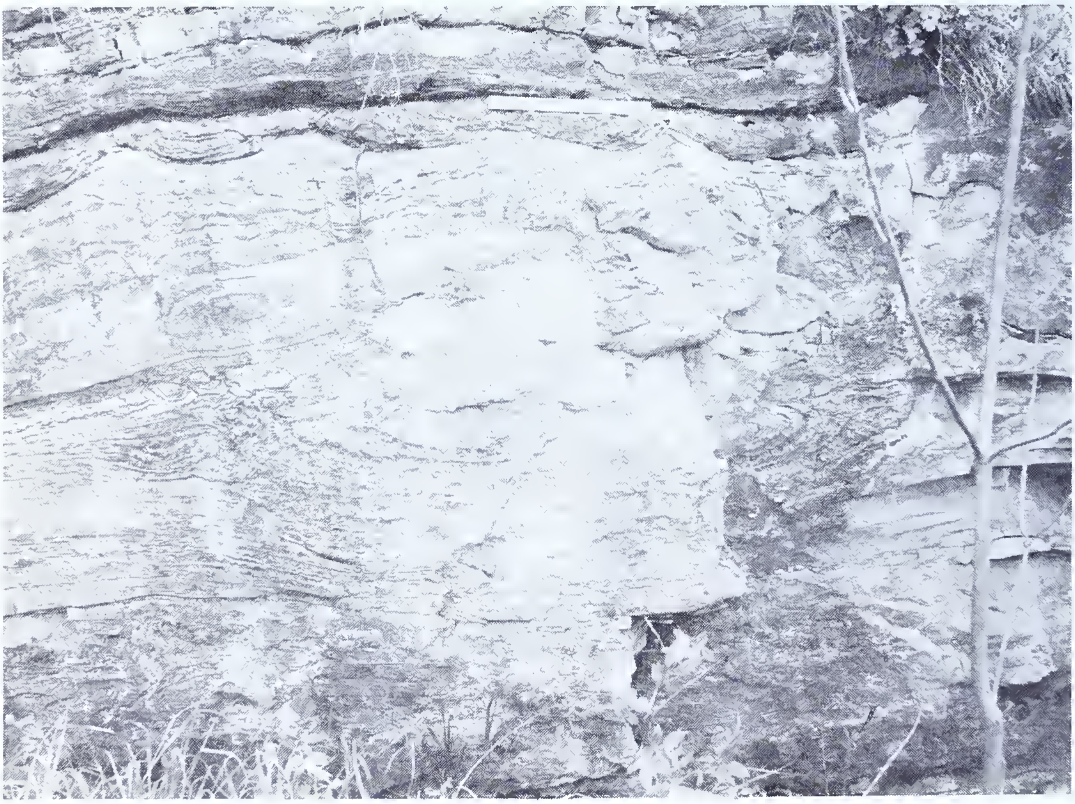


Figure 15. Stromatolites of the cryptozoon type in the Millbach Formation near Sheridan, Lebanon County.

Stromatolites, typical of those which occur in the middle member, are shown in Figures 14 and 15; these are of the cryptozoon type but vary widely in characteristics. Figure 14A shows individual cryptozoon that are 1/2" to 3/4" in diameter and a bioherm that is 2'3" in height. The limestone in the center of the bioherm is extremely porous and pinkish gray to lavender in color. However, limestone making up the remainder of the bioherm is light gray with dark gray mottling. Dark-gray oolites are also present in several of the beds of limestone.

The cryptozoons illustrated in Figure 14B are one inch to a maximum of two inches in diameter. The bioherm is six and one half feet in length and nine inches in height. A light-purple-colored limestone is typical of the outer margins of the bioherm whereas the central portion of the structure is pinkish-gray, marbeloid, and vuggy.

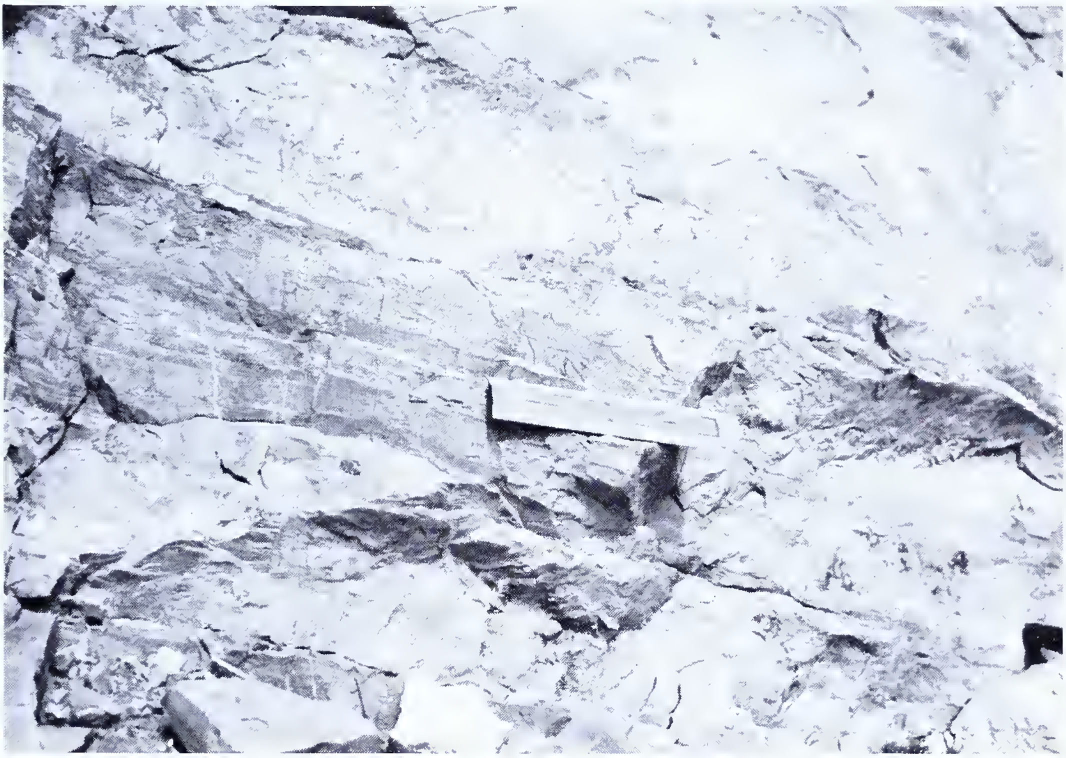


Figure 16. Stromatolites of the gymnosolen type in the Millbach Formation near Sheridan, Lebanon County.

Only one example (Fig. 16) of the gymnosolen type of stromatolite was found in the Womelsdorf quadrangle. This bioherm consists of branching, laminated, cylinder-like structures.

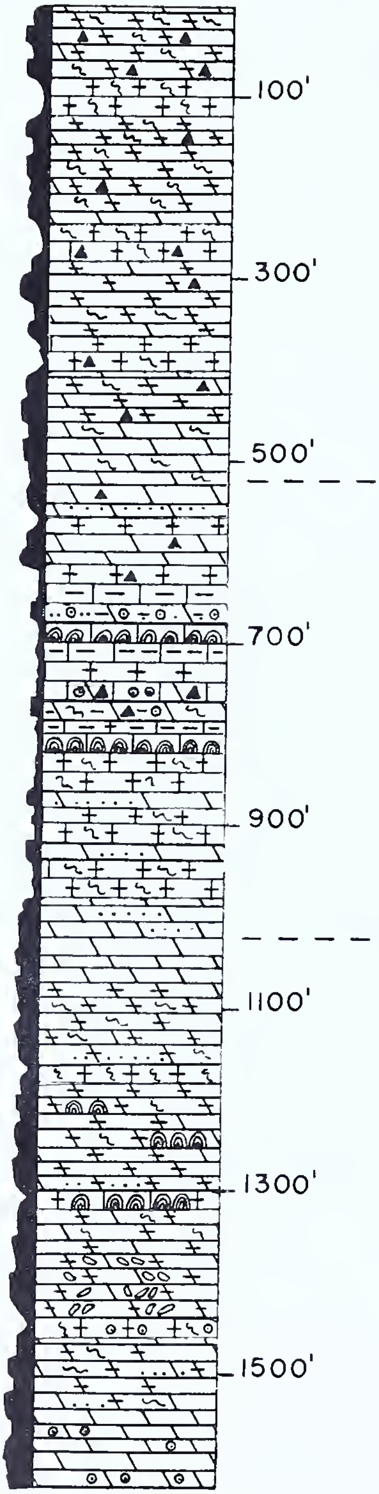


Figure 17. Generalized composite section of the Richland Formation, Womelsdorf quadrangle.

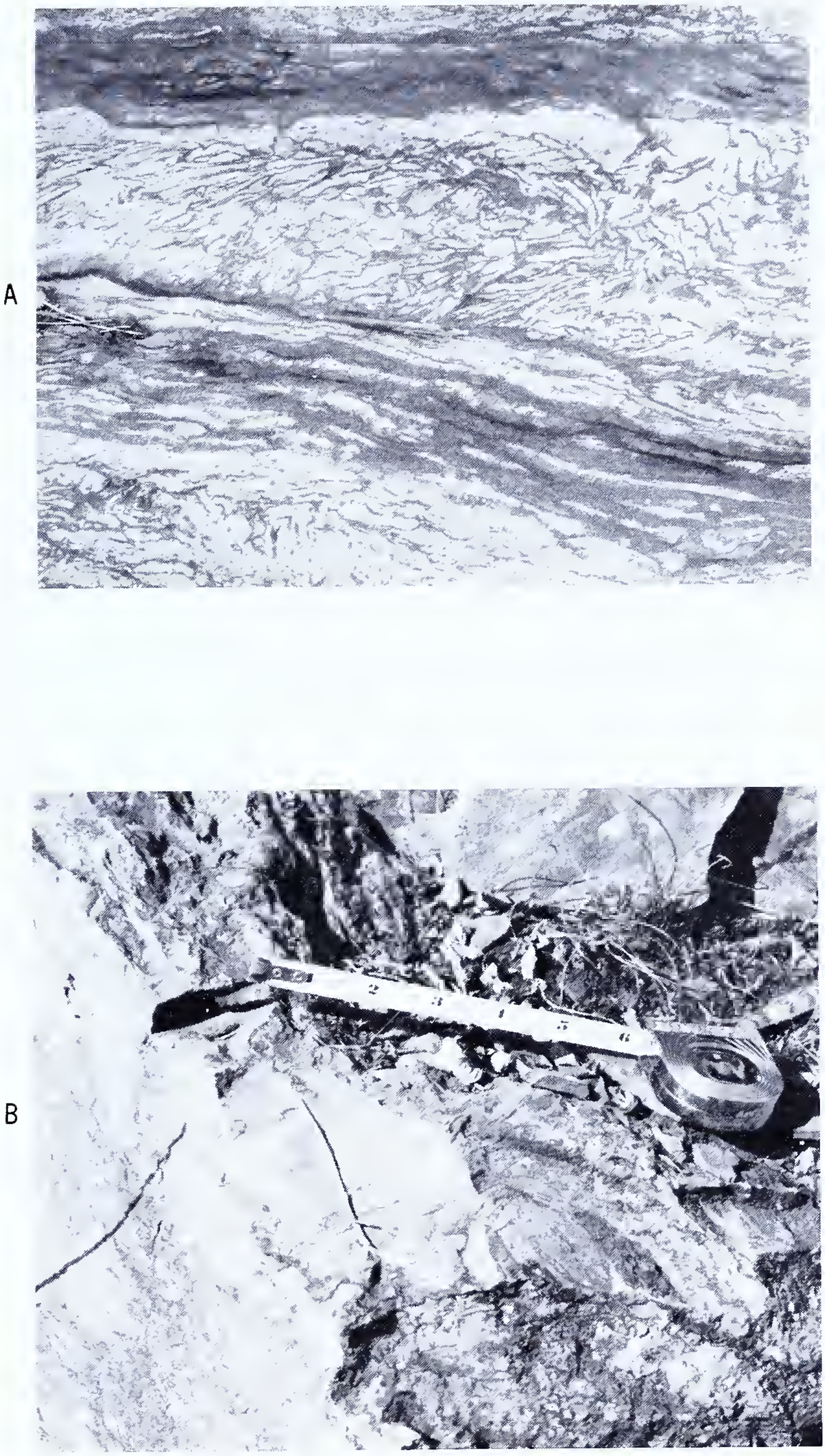


Figure 18. "Flat -pebble" breccia layers in the lower portion of the Richland Formation at Sheridan, Lebanon County.

An approximate thickness in the Womelsdorf quadrangle has been calculated to be 1450 feet. This formation increases in thickness from western Lebanon County where it is approximately 550 feet thick to this quadrangle's estimated thickness of over 1000 feet.

Exposures are generally good, the most notable being a small quarry south of Sheridan, along Mill Creek (see Stratigraphic Sections, Locality 3 in Appendix). Another series of excellent exposures is locate along the Reading railroad tracks immediately east of Newmanstown.

Richland Formation

The Richland Formation is predominantly a dolomite sequence that stratigraphically overlies the Millbach Formation.

The lower sectionof the Richland is composed primarily of mediu dark-gray to dark-gray, finely to medium-crystalline, thin- to massive-bedded dolomite. The dolomite beds weather light olive to yellowish gray A few dark-gray, finely crystalline limestones are interbedded with the dolomite. These limestones are easily distinguishable in that they weath medium gray as opposed to the yellowish-gray weathered surface of the dol mites. Quartz veins, oolites, stromatolites, "flat-pebble" breccias (Fig 18), sandstones, and shaly laminations all occur within this part of the formation.

The middle part is composed primarily of medium-light-gray, medium-crystalline dolomite containing minor amounts of dark-gray chert, oolites, and shaly laminations. Thin beds (less than 1") of porous sandstone are common.

Figure 19. Dark-gray chert beds, pods, and lenses in light-gray weathering limestone of the Richland Formation near the Borough of Richland, Lebanon County.

Individual beds of dolomite in this middle part are interbedded th thick beds of medium-light-gray to dark-gray, medium-crystalline lime-one. This limestone contains regular, shaly laminations, oolites, breccia, yptozoon structures, and dark-gray to medium-gray nodular chert (Fig. 19). ese interbedded limestones weather medium gray and are easily distinguished om the dolomite beds that weather light olive gray to yellowish gray.

The upper part of this formation is composed chiefly of medium-ght-gray, finely crystalline, massive-bedded dolomite. It contains chert d sand lenses (Fig. 20). This dolomite weathers light olive gray and is terbedded with finely crystalline, medium-dark-gray, massive-bedded mestone. This limestone contains shaly laminations, dark-gray chert nses and nodules, and calcite blebs. The weathered surface of the lime-one is medium light gray to light olive gray. The top is mapped at the se of the first thick bed of medium-light-gray limestone containing inoid and other fossil fragments (Fig. 17).

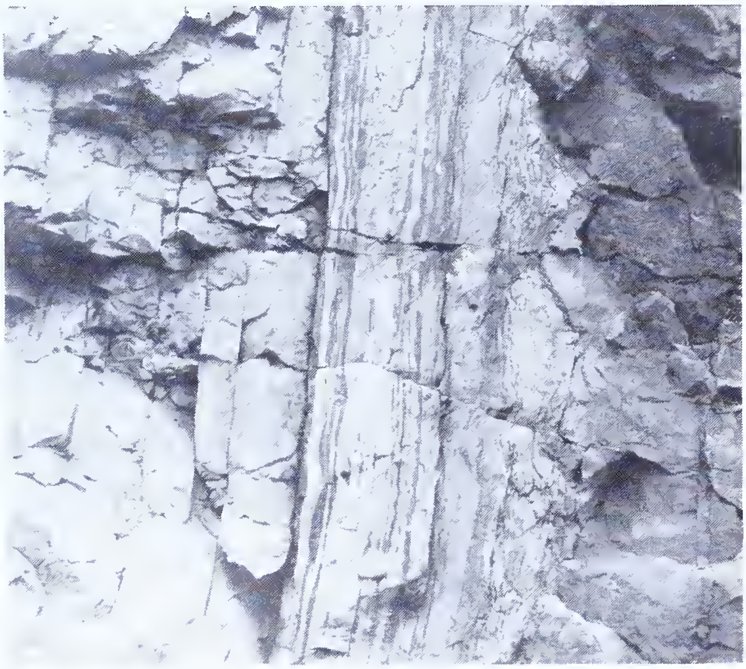


Figure 20. Yellowish-gray sand beds and lenses in beds of light-olive-gray weathering dolomite of the Richland Formation exposed along the Reading Railroad tracks east of the Borough of Richland, Lebanon County.

This formation is best exposed in the Womelsdorf quadrangle where exceeds a thickness of 1700 feet. The formation increases in thickness om west to east; at Lebanon, Pennsylvania, it is 800 feet thick and at chland 1300 feet thick.

Outcrops of the Richland Formation are numerous along the Rich-nd-Sheridan road, the Reading Railroad tracks along the western edge of the quadrangle, and immediately south of Womelsdorf. Two of these locati along the Richland-Sheridan road and the Reading Railroad tracks, are described in the Appendix (Localities 4a and 4b).

Ordovician System

Beekmantown Group

Stonehenge Formation

The oldest exposed Ordovician rocks in the Womelsdorf quadrangle are correlated with the Stonehenge Limestone of south-central Pennsylvani as defined by Stose (1908) in the vicinity of Mercersburg and Chambersbur This author has been able to map these rocks almost continuously from the Carlisle area, Cumberland County, to the Lebanon-Berks County line where J. P. Hobson, Jr. (1957) lists fragmentary fossil evidence that suggests these rocks should be correlated with the Stonehenge of south-central Pennsylvania.

The contact between the Stonehenge and underlying Richland Formation has been placed at the base of a pure medium-gray limestone unit above the upper dolomite sequence of the Richland Formation.

The lower member of the Stonehenge is composed of medium-dark-gray, finely crystalline limestone containing shaly laminations that exceed 1/2" in thickness and weather dark gray to black. "Flat-pebble breccia" beds and irregular masses (Figure 21), and lenses and pods of calcarenite are common. Dark-gray chert lenses and shaly bands and ribbo stand out in relief to make a striking contrast. Beds range in thickness from several inches to several feet. Thin beds of medium-gray, finely crystalline dolomite are irregularly interbedded with the limestone. Thi beds of crinoid fragments and other fossil debris occur in this lower member.

The upper member is characterized by medium-gray, finely crystalline, massive-bedded limestone and lenses, pods, and beds of calcarenite. Thin shaly or silty laminations are frequent.

The exact thickness of the Stonehenge cannot be determined but i is estimated from its width of outcrop in the quadrangle to be approximately 400 feet. The Stonehenge increases in thickness toward the west. South of the city of Lebanon, it is approximately 1250 feet thick and farther to the west near Annville it is 1500 feet thick. To the east in the Reading quadrangle, Berks County, Hobson (1957) reports the thickness to be 250 feet.

Numerous outcrops of the Stonehenge may be found north and east of the Borough of Richland in the northwest corner of the quadrangle. Th reference section for the Stonehenge in the Lebanon Valley has been described by Hobson (1963, p. 263).

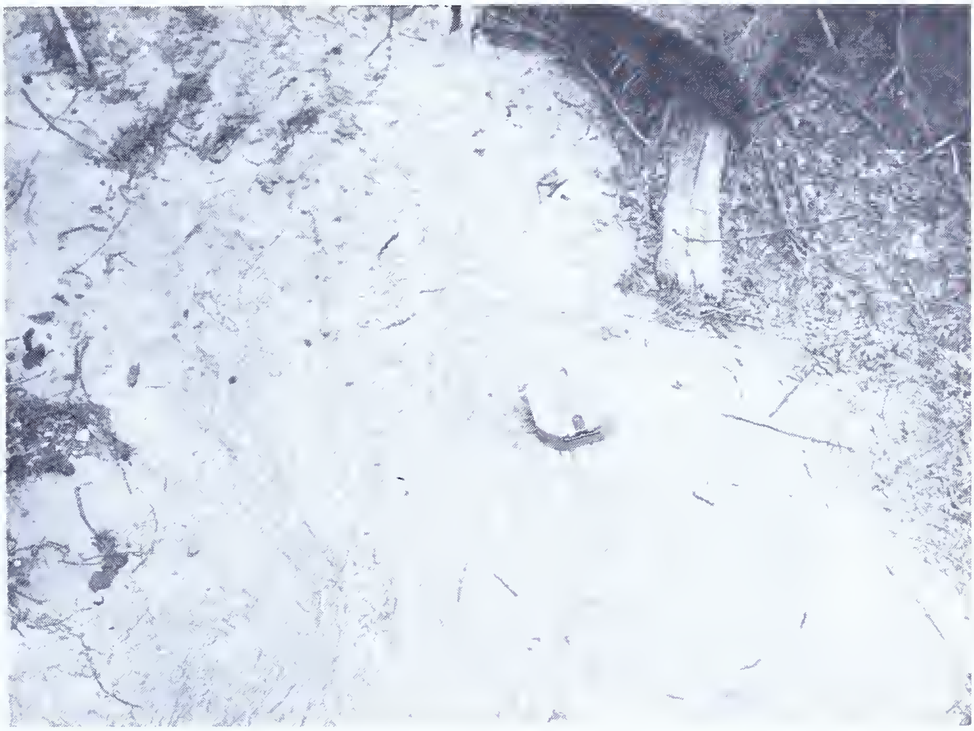


Figure 21. "Flat-pebble" breccia beds in the Stonehenge Formation. Outcrop is located approximately 2 miles south of the Borough of Myerstown, Lebanon County.

Rickenbach Formation

The Rickenbach Formation (Hobson, 1957) is the dolomite sequence that overlies the Stonehenge limestone. The base of this unit is placed at the first appearance of medium-light-gray, finely crystalline dolomite. A reference section for this formation in Lebanon County is described in the Appendix (Locality 5).

The lower member of this formation in the Womelsdorf quadrangle consists of medium-light-gray, medium crystalline dolomite with lenses and pods of light-gray to white chert.

The upper member is characterized by medium- to medium-dark-gray, coarsely crystalline, massive dolomite containing light-gray and dakr-gray chert. Blocky fracturing is characteristic. The dolomite weathers light olive gray.

This formation reaches an approximate maximum thickness of 800 feet in the Womelsdorf quadrangle.

Epler Formation

The Epler Formation (Hobson, 1957) is an interbedded limestone and dolomite sequence that overlies the Rickenbach Formation. The base of this formation is placed at the first thick, light-gray limestone bed.

The lower member consists of medium-light-gray, medium to finely crystalline, thin-bedded limestone. Thin shaly laminations and chert nodules are found frequently in these beds. Medium-gray to medium-light-gray, finely crystalline dolomite is interbedded with the limestone. Quartz veins are most pronounced in the dolomite.

The middle member of the Epler is composed of medium-dark- to medium-gray, thin-bedded limestone. Calcarenite beds are common. Beds of pinkish-gray limestone with shaly laminations are found at several horizons within this unit. Limonite nodules and geodes and chert lenses and pods are not uncommon in the "float" from this member.

The upper member contains medium-gray to dark-gray, thin to platty bedded limestone. Calcarenite beds are also present in this unit. Shaly laminations and chert lenses also occur in the limestone. Medium-light-gray to medium-gray, coarsely crystalline dolomite is interbedded with this limestone. The dolomite varies in thickness from thin beds (less than 1") to massive beds several feet thick. Chert lenses and calcite veins are common in the dolomite.

A reference section is described in the Appendix (Locality 6). This section is located in the Richland quadrangle along the Reading Railroad about 0.3-mile west of the Borough of Richland. Exposures of the Epler are numerous along old Route 422 east of Womelsdorf.

The thickness of the Epler Formation in the structurally complex Womelsdorf quadrangle is difficult to estimate but is at least 650 feet.

Ontelaunee Formation

The Ontelaunee Formation (Hobson, 1957) is the uppermost formation in the Beekmantown Group in the Lebanon Valley. The base of this formation is placed at the first appearance of the dark-gray chert beds that are present everywhere at this stratigraphic horizon throughout the Lebanon Valley.

Approximately four feet of dark-gray to light-gray mottled chert beds (Figure 22) mark the extreme base of this unit. Several weathered outcrops of this chert show a partial leaching of the chert or cherty dolomite.

Beds of medium-gray to medium-light-gray, coarsely crystalline dolomite occur stratigraphically above the chert. The top of the formation is drawn at the top of the uppermost bed of medium-gray to dark-gray, coarsely crystalline dolomite.

An exact thickness of this formation in the quadrangle cannot be determined because of the complexities due to thrust faulting and flowage of the carbonate rocks.

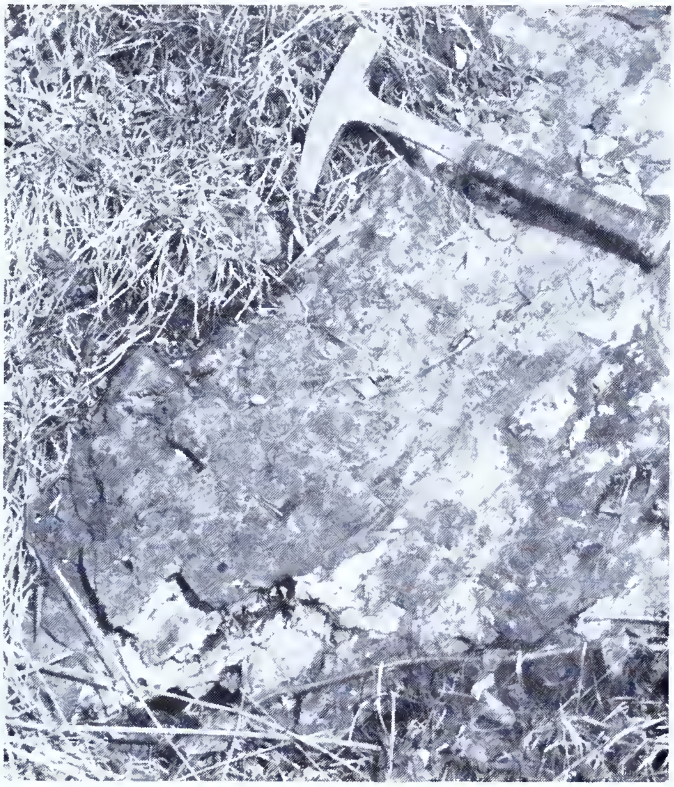


Figure 22. Dark-gray chert bed at base of Ontelaunee Formation. Outcrop at intersection of old Route 422 and Tulpehocken Creek.

The best exposures of the chert horizon may be found along the Tulpehocken Creek in the northwest corner of the quadrangle. The best reference section for this formation in the Lebanon Valley is found at an abandoned quarry 0.15 mile west of Coheva, adjacent to the northwest borough limits of Lebanon. This section is described by Hobson (1963, p. 283).

Annville Formation

The Annville Formation (Prouty, 1959) overlies the Beekmantown Group in this quadrangle. It is a relatively homogeneous, high-calcium limestone formation.

The Annville is a massive-bedded, finely crystalline, light-gray, high-calcium limestone. It weathers to a white sugary-looking rock with a fluted surface. This fluting is a striking feature of the Annville and is caused by the differential weathering of the bedding laminae, and in some places, cleavage planes. The top is drawn at the base of the first dark-gray, carbonaceous limestone bed of the overlying Myerstown Formation.

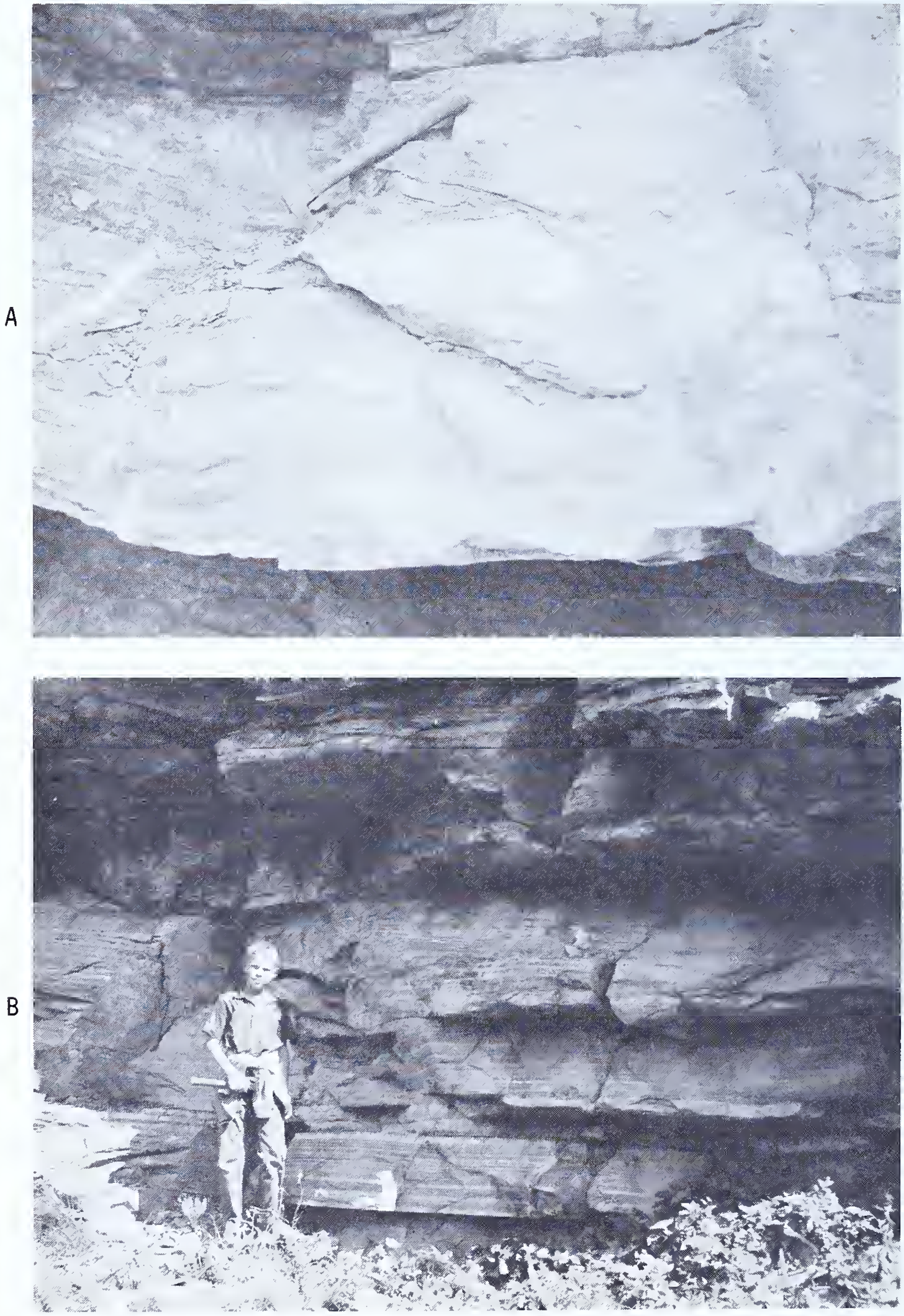


Figure 23. Small quarry in Hershey conglomerate, one-half mile northwest of Womelsdorf, Berks County.

Stratigraphic and structural complexities account for an eastward thinning of this formation.

Outcrops of the Annville Formation may be found in the fields near the intersection of old Route 422 and the Tulpehocken Creek. This formation is quarried extensively for flux stone, lime and road stone.

Myerstown Formation

The Myerstown Formation (Prouty, 1959) unconformably overlies the Annville Formation. It is essentially a thin bedded, medium-dark-gray to dark-gray, medium to finely crystalline limestone. The basal beds are dark-gray to black carbonaceous limestone that contrast strongly with the older Annville Formation. Beds of coarse calcarenite are common. Four beds of metabentonite were observed in exposures of this formation just north of the quadrangle boundary.

At one locality in the quadrangle beds of dolomite pebble conglomerate, similar to those in the overlying Hershey Formation, occur in beds of typical Myerstown lithology.

Weathered fragments of Myerstown occurring as float in the soil are light gray and have characteristic rounded platy forms that are easily distinguished from adjacent formations.

The upper contact with the Hershey Formation is nowhere exposed in the area. The mapping is based on the presence of the characteristic fragments in the soil.

Hershey Formation

The Hershey Formation (Prouty, 1959) overlies the Myerstown limestone and is itself overlain by non-calcareous, brownish-gray shale of the Martinsburg Formation.

A basal conglomerate (Figure 23) of the Hershey contains boulders of dolomite that are quite angular, and sometimes reach several feet in diameter. This conglomerate is best exposed along new Route 422 about one mile east of Stouchsburg.

The Hershey is a dark-gray, carbonaceous, silty limestone. Upon weathering, the lime content of the rock is often leached and brownish-gray chips of the non-calcareous rock appear in the soil.

The Hershey Formation occurs over large areas in the northeastern corner of the quadrangle but outcrops of it are rare. The formation is usually represented at the surface by float which is extremely difficult to distinguish from the shale fragments of the overlying and transitional Martinsburg Formation. Because of this transitional relationship with the Martinsburg, the upper contact of the Hershey is an approximation.

Martinsburg Formation

Only two areas in the northeast corner of the quadrangle are underlain by Martinsburg shale (Keith, 1894). Where it is predominantly medium gray to dark gray, it weathers to a light-brownish-gray color. The contact between the Martinsburg shale and the underlying limestones is in part marked by faulting.

STRUCTURE

General Statement

The Womelsdorf quadrangle is the third 7-1/2' quadrangle mapped in the Lebanon Valley section of the Great Valley physiographic province. Structurally, this quadrangle is an important segment of the Great Valley in eastern Pennsylvania.

The regional setting involving the carbonates is a complex anticlinorium that is overturned to the north. Throughout much of the Lebano Valley the anticlinorium is completely overturned and essentially recumbe Minor folds are mappable and may be viewed at many locations in the valle Both the large and smaller recumbent folds are accompanied by thrust and tear faults.

As far back as 1883, Frederick Prime, a geologist for the Secon Geological Survey of Pennsylvania, summarized the geologic structure in this area in the following words: "Level as the general surface may be, it is the planed-off section of as gnarled and twisted a piece of the earth's crust as can be found in any country. Although these plications are comparatively small they are of the same nature as the gigantic overthrown anticlinals of the Alps and Apennines." The results of the presen mapping certainly support Prime's interpretation.

Folds

Folds in the carbonate rocks of this quadrangle and in the immediate surrounding area have axes that trend nearly east-west. The folds are essentially recumbent and the axial planes horizontal. All folds present in the quadrangle occur on the overturned limb of a major anticlinor whose roots lie somewhere to the south. Stretching in this overturned li is evidenced in the Womelsdorf quadrangle by such features as boudins (Fi 24), stretched stromatolites (Fig. 14A), and stretched oolites. They are commonplace and are indicative of a strongly overturned limb of a major fold. Widespread overturning and recumbent folding are in turn evidence of large or intense horizontal tectonic transport of the rocks. The direction of this tectonic transport in this quadrangle is approximately 30 degrees to the northwest (Fig. 25).

In an area were axial planes are nearly horizontal such as the Lebanon Valley, anticlines and synclines are difficult to distinguish fro each other. As an anticline becomes truly recumbent, it will be advanced farther in the direction of tectonic transport whereas the adjacent structure, the syncline, will remain stationary or be retarded. In the Lebanon Valley, and locally in the Womelsdorf quadrangle, it may be said that folds concave to the north or northwest are synclines and those convex to the north are anticlines. This is true, however, only if the fold have essentially horizontal axial planes.

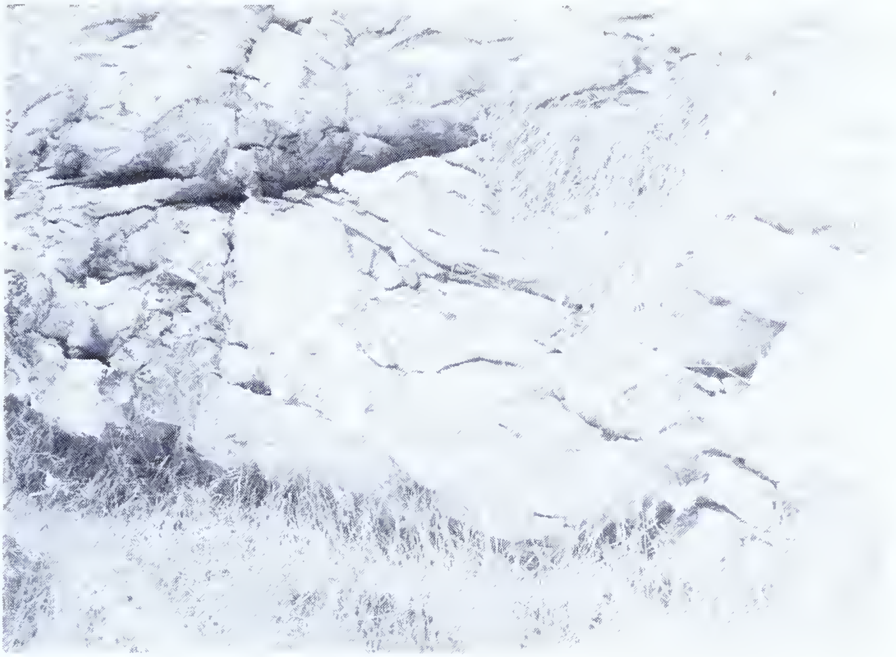


Figure 24. Boudinage structures in the Richland Formation near Richland, Lebanon County.

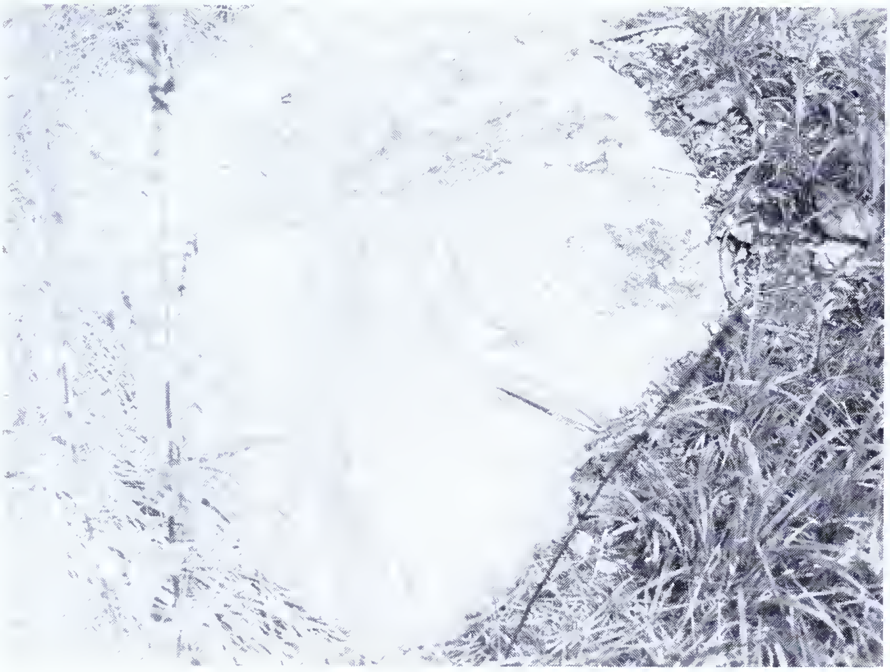


Figure 25. Lineation produced by slippage of beds and indicating trend of regional tectonic transport.

The Precambrian granite gneiss and associated rocks of South Mountain may represent an isolated segment of the crystalline basement r over which these carbonates and quartzites were originally deposited. A the time these folds were being formed, this basement reminent was torn away from its roots and transported to the north-northwest with the carb ates. Today, South Mountain lies on top of the overturned limb of a lar recumbent fold of carbonate rocks and is itself rootless. Aeromagnetic surveys of this area (Bromery, 1960) provide partial proof of this geolo interpretation for they indicate the approximate thickness of the crysta line rocks in South Mountain to be less than 2500 feet.

Minor folds associated with the major recumbent folding of the Lebanon Valley range in size from sub-megascopic to structures that are easily mapped and shown on the geologic map (Plate 1.). These minor fol are often called digitations, plications, or fingers of the major fold structures. Complex minor folding can be observed at several places in Womelsdorf quadrangle. The best exposure of these minor folds is visibl in a small quarry north of the old route 422, about one-half mile west o Womelsdorf.

The overturned folds and miles of gentle south-dipping rocks i the Lebanon Valley can truly be termed alpine structure.

Faults

Folding in the carbonates and associated rocks of the Lebanon Valley is accompanied by both thrust and tear faulting. Several example of each are present in the Womelsdorf quadrangle.

Usually a fault plane cannot be actually seen in the field but conclusive evidence for the fault is often present. Such is the case of the tear fault northeast of the Borough of Newmanstown. At the top of t Millbach Formation there is a sandy dolomite unit that weathers to a dar brown, very porous sandstone. This sandstone float can be traced from north of Millbach on the west side of the quadrangle to immediately nort of the railroad bridge at the east end of Newmanstown. It is at this loca tion that it disappears as if cut off by a sharp knife. This same sands is not seen directly east of this spot in this quadrangle but rather sev thousand feet to the south.

Thrust faulting within the Womelsdorf quadrangle is a striking feature. Four major thrust faults are present and can be traced over ma miles. Most of these thrust faults terminate into bedding-plane thrusts and account for apparent thickening of a formation. Within some formati many bedding-plane thrust faults are probably present but are impossible to map. An example of this type of thrust may be seen on the geologic m (Plate 1) in the Buffalo Springs Formation in the vicinity of Millbach Church.

TRIASSIC ROCKS

by

Dean B. McLaughlin

STRATIGRAPHY

Newark Group

General Statement

The Newark Group sediments are composed of detritus which is ught to have been derived from erosion of Paleozoic and Precambrian rocks areas immediately adjacent to the site of Newark sedimentation. Newark ks in Lancaster County and vicinity are shales, sandstones and conglom- tes in addition to intrusive sills and dikes of diabase. The sediments divided into two formations. The lower is the dominantly feldspathic Oxford Formation which occurs south of this quadrangle. Its uppermost s approach within 1,000 feet of the southern edge of the area just south Furnace Hills Camp. The upper part of the Newark Group, the Gettysburg mation, consists of red shales, red quartzose sandstones, and quartz glomerates, with local bodies of shale conglomerate.

No single, well-exposed stratigraphic section occurs in the elsdorf quadrangle. To the west, in the Richland quadrangle, the Getty- rg section along Hammer Creek is 9,400 feet thick. The same conglomerate sandstone units in that area have been traced into the Womelsdorf drangle and a similar thickness is inferred there.

Along the northern edge of the Newark outcrop belt in this area there strong evidence of a fault along which Newark rocks have dropped down ative to Cambrian and Precambrian rocks of South Mountain. Immediately t of this area, near Shaefferstown in the Richland quadrangle and at nwall in the Lebanon quadrangle, Newark beds overlap Paleozoic rocks at border (north) of the belt.

Gettysburg Formation

The Gettysburg consists of red shales, red, brown, and gray sand- nes, and fine to coarse quartz conglomerate, all of which are interbedded some extent. Conglomerate is dominant in Furnace Hills along the thern edge of the quadrangle, and shale and sandstone are common in the land immediately north of Furnace Hills. Locally, along the north border the Newark outcrop belt, there is conglomerate composed of Ordovician tinsburg shale fragments. Such conglomerate seems to support the othesis of local derivation of Newark sediments.

Gettysburg red shale, typically nonmicaceous is interbedded nearl everywhere with siltstone and sandstone. The shale is thin to medium bed usually friable, never fissile, and has a hackly fracture. Thin bedded varieties usually have wavy or uneven bedding. Ripple marks and mudcrack are present.

Sandstone is the most common rock type of the Gettysburg and is t dominant type in much of this area. The sandstones range in color from r through brown to light gray; red and brown sandstones are common. Some sandstones in Furnace Hills area are nearly white. The writer believes t hematite, which may act as a colorant in Newark sediments, has been leach from these white sandstones.

Sandstone-bedding thickness ranges from one or two inches to a fo or more. Cross bedding, lensing, and channelling are fairly common, thou some of the finer sandstones have a thin bedding that is quite uniform fo a number of yards. Ripple marks occur in some of the finer sandstone bed Grain size ranges from very fine to coarse; in general, the thin bedded varieties tend to be fine grained. The finer sandstones and siltstones a well sorted, but coarser varieties are usually rather poorly sorted.

Gettysburg sandstone is composed principally of angular to subrou colorless quartz grains and a small percentage of miscellaneous rock fragments imbedded in a matrix of clay-size material with hematite. Feldspat sandstones are absent in the Gettysburg of this area and are extremely ra elsewhere in the formation. Gettysburg sandstones grade on the one hand siltstones with a high percentage of matrix, and on the other into conglo- erates.

Coarse quartz conglomerates form many narrow ridges throughout mu of this area of Newark rocks; such as Kline Hill, Black Oak Ridge, and Laurel Ridge. The conglomerate is typically thick bedded and occasionall is so massive that bedding is difficult to recognize in small exposures. Almost everywhere minor sandstone interbeds occur in the conglomerate. Pebbles and cobbles of quartz, quartzite, and sandstone are densely to sparsely distributed in bands and lenses from one to two inches up to man feet in thickness. Cobbles up to 5 or 6 inches in diameter occur in some the thickest beds. One 15-inch boulder of quartzite was seen in the cong erate just north of Cocalico. Most of the conglomerates in this quadrang however, consist of pebbles less than 2 inches in diameter. Bands and lenses of large cobbles or pebbles alternate with beds containing smaller pebbles, or with beds of sandstone which occasionally contain a few pebbl The conglomerates grade into pebbly sandstones with decrease in dimension and number of pebbles.

Occasionally pebbles and cobbles in these conglomerates are nearl touching with groundmass filling only the interstices. More commonly groundmass forms 50% or more of the rock. The groundmass of the conglom is essentially similar to the composition of the coarser sandstones. It consists chiefly of angular to subangular grains of quartz, tiny fragment of quartzite, and occasionally fine sandstone and other rock fragments al of which are bound together by a matrix of clay-size material with hemati present. Some of the white to gray conglomerates appear to be cemented b ica and to a minor extent, by calcite.

Local variations in the character of the conglomerate are thought offer significant clues to the sources of Newark sediments. Conglomerates ch extend into this quadrangle from the Richland quadrangle to the west be grouped into conglomerates of the lower portion of the Gettysburg and glomerates of the upper portion. Between these two portions of the tysburg is an area that measures about one mile from north to south ross strike) in which the rock type is almost entirely sandstone and shale.

The conglomerates in the lower part of the Gettysburg Formation occupy area of Furnace Hills and attain a maximum thickness in the Richland drangle to the west. The conglomerates in the Womelsdorf quadrangle, y beds of which are thin and discontinuous. represent fingering out of ger lenses from their greatest thickness in the vicinity of Hammer Creek the west. The thickest conglomerate unit is that which forms the crest Black Oak Ridge. Eastward along strike, this conglomerate body inter- gers with sandstone halfway between Middle Creek and Furnace Hills Camp, n recurs as detached lenses of conglomerate farther east. Another body conglomerate, probably at the same stratigraphic horizon, is prominent th and southwest of Kline Hill, and is offset by several faults. It thins tward and grades into sandstone. Farther east along strike, conglomerates m ridges and extend to the eastern edge of the quadrangle.

Change in size and number of pebbles gives further evidence that the glomerate fingers out eastward. At the western edge of the quadrangle, conglomerate of Black Oak Ridge has pebbles and cobbles up to 4 inches, occasionally 6 inches, in diameter. In some beds they form a large centage of the rock. Eastward, this most prominent unit has smaller and er pebbles. The rock, thus, becomes a pebbly sandstone toward the east. er conglomerates in Furnace Hills likewise have generally fewer and ller pebbles toward the east than to the west. Cross beds have been sured in several places and their orientations indicate that depositing eams flowed eastward or southeastward.

A large portion of the pebbles in the lower conglomerate of the tysburg are light-gray, fine- to medium-grained quartzite. A small tion are conglomeratic quartzite. On the evidence of close lithologic emblence, these are identified as Silurian Tuscarora quartzite which is osed about fifteen miles north of the Triassic north border. A ttering of brownish and reddish-brown, fine-grained sandstone pebbles have been derived from Silurian Clinton or Bloomsburg Formations. A ge percentage of the smaller pebbles are vein quartz. No limestone bles, chips of Martinsburg shale or any recognizable Precambrian rock gments have been noted in the conglomerates of Furnace Hills.

Conglomerates which comprise the upper part of the Gettysburg mation differ somewhat from those in the lower part. They are not well solidated and are associated with lenses and interbeds of shale conglom- te. The largest cobbles are brittle, highly vitreous, light- to dark- y quartzite that is believed to be Cambrian (Hardyston ?) quartzite ch forms the western flank of South Mountain. This quartzite may have covered much of the mountain area during Triassic time. Supporting this view is the fact that no fragments of Precambrian rock have been identif in these conglomerates, suggesting that the Precambrian core of South Mountain was not exposed when these Newark sediments were deposited.

Most pebbles in the upper part of the Gettysburg are smaller tha 3 inches in diameter, although locally they are larger. In the area at north border of Newark rocks, directly north of Cocalico, 6-inch cobbles are abundant. A few exceed one foot in diameter.

Northeast of Cocalico several conglomerate units with a north-so strike have been traced for a mile or more from the north edge of the Newark outcrop belt. They contain pebbles of vitreous quartzite that ar similar to Cambrian (Hardyston ?) quartzites now exposed to the north. That such conglomeratic units are a border facies of the Gettysburg Formation is suggested by the rapidity with which size and number of pebbles diminish with increasing distance from the border.

Conglomerate of Laurel Ridge is the western end of an extensive conglomerate body that reaches its maximum thickness in the Sinking Spri quadrangle to the east. It resembles the conglomerate in the lower part the Gettysburg but is stratigraphically higher. Pebbles and cobbles in Laurel Ridge occasionally attain 4 or 5 inches in diameter and are chief gray quartzite that is identified as Silurian Tuscarora quartzite. Decrease in dimension and number of pebbles indicates that the depositin stream flowed westward. A few cross-bed measurements also suggest this.

The thin and lensing conglomerate unit underlying the crest of Kline Hill resembles the unit of Laurel Ridge with the exception of its smaller pebbles. However, it probably lies at a considerably lower stratigraphic position than the conglomerate of Laurel Ridge if the interpretation of the fault north of Kline Hill is correct, that is, the downthrown side to the north.

Shale conglomerate occurs in a well-defined area that extends ea and west from Cocalico. It interfingers with quartzite conglomerate and its interbedded sandstones. This rock is a jumbled mass of poorly sorte fragments of Martinsburg shale in a reddish argillaceous matrix. Beddin is very uneven and ranges from less than one inch to several inches thic Scattered pebbles of vitreous quartzite are associated with the shale fragments. These pebbles may have been derived from the Hardyston quartzite which now crops out in nearby South Mountain. The shale congl erate was evidently of local derivation. It adjoins a small area in whi Martinsburg shale crops out at the foot of South Mountain north of Cocal This body of shale may be a part of the floor on which Newark sediments were deposited. The association of conglomeratic fragments is similar t that described in the Richland quadrangle (Gray, et. al., 1958). There, shale conglomerate exposed southeast of Schaefferstown lies adjacent to large area underlain by Martinsburg shale. The juxtaposition of source rock and sediment strongly indicates overlap of the Newark upon the adjoining Paleozoic rocks.

A few small lenses of shale conglomerate have been mapped west o ocalico and south of Kleinfeltersville, where the lenses are intimately ssociated with quartz conglomerates. Another patch of shale conglomerate ies about a mile east-northeast of Union House. Its southwestward extent ay be greater than indicated on the map, but overlap by Pleistocene or ecent alluvium conceals its distribution.

The Triassic Gettysburg sediments of the Womelsdorf quadrangle are hought to represent large, merging alluvial fans the apices of which were t the north border to the west and east of this area (McLaughlin, 1939). n the lower portion of the Gettysburg the greater part of the sediments re part of the western fan. Later, during the time of Gettysburg sand-tone and shale deposition which succeeded deposition of the lower part of he formation, this western source seems to have been less important and ost of the detritus was associated with the eastern fan, the gravels of hich form Laurel Ridge. At the time during which the rocks in the upper ortion of the Gettysburg were deposited, there were apparently two or ore streams eroding the South Mountain area and the adjoining areas of artinsburg shale. This resulted in the complicated interfingering of hale conglomerate and the conglomerate containing Hardyston quartzite obbles. The Gettysburg sediments, from evidence of fan shape, and hanges in pebble size and number, were derived apparently entirely from aleozoic rocks which were then exposed north of the area of Newark edimentation.

Igneous Rocks

East and west of the Womelsdorf quadrangle there are large diabase ntrusions that range from fine to coarse grained. The diabase in the omelsdorf quadrangle is fine grained, dark gray to black composed chiefly f gray plagioclase feldspars and black or greenish-black pyroxene. At the ediment-diabase contact, the grains in the chilled zone are, in places, nvisible to the naked eye.

In this quadrangle only a few dikes occur and are of minor areal mportance. The only prominent intrusive body in this quadrangle is a dike, he total length of which is about three miles; its maximum width is about 00 yards. It extends from the foot of Laurel Ridge southwestward, passes ast of Blainsport and continues to the southern edge of the area. Locally, t Cocalico Creek, its continuity is interrupted and offset by a fault. hroughout its areal extent it cuts across a thickness of about 5,000 feet f Gettysburg sediments. The course of the dike is marked by a distinct idge, probably due in part to the induration of the enclosing sediments. here are no indications of the dike on the aeromagnetic map of this egion (Bromery, et. al., 1960).

Immediately adjacent to the dike the sediments are thermally etamorphosed and discolored within a width of a few yards of the contact ith diabase. About a half mile south of Blainsport the color effects in he soil of a tobacco field are particularly striking. The weathering of he dike produces a bright orange-brown soil resulting from oxidation of ron minerals and decomposition of feldspar in the diabase. On either side of the intrusive is a band of gray or lavender-tinted soil resulting from baking of the sediments. This color grades into the typically reddish soil that is characteristic of unaltered Gettysburg sediments.

Two small dikes were traced for about 200 yards near Union House, and about a mile north of there another small dike is close to the north border of the Triassic.

STRUCTURE

The structure of the Triassic rocks in this quadrangle is a homocline, broadly warped and block-faulted, with a local plunging synclin near the north border. The north border itself, over most of the width of the quadrangle, is a major fault with a displacement of several thousand feet. The Triassic strata, in general, dip toward the north at angles of from 20 to 50 degrees.

Part of a westward-plunging syncline, the north limb of which is cut off by the north border fault, occupies an area somewhat more than a mile wide from north to south, and lies between Harnish Run and Cocalico. Several conglomerate units have a north-south strike at the border and thei trend changes to south-westward and westward away from the north border. Dips along the nose of the syncline are moderately steep westward.

Indications of a major fault at the north Triassic border are abundant. The ridge of Cambrian quartzite that forms the western flank of South Mountain is abruptly truncated by the fault. Several northward-striking Triassic conglomerate units northwest of Blainsport are cut off at the foot of South Mountain. Shearing and slickensiding of the Triassic sandstones are seen at many places close to the border. Within several hundred yards of the border in the area between Kleinfeltersville and Cocalico, the sandstones are highly indurated by silicification. In the same area numerous slickensided fragments of sandstone attest to extensive brecciation and movement along minor faults associated with the major one. An outcrop of Triassic sandstone close to the border north of Blainsport is considerably sheared and slickensided and dips southward, probably due to drag by this fault. Along the road at the north foot of Laurel Ridge strongly sheared Cambrian quartzite crops out within a few yards of the Triassic. Farther east along the same road in the adjacent Sinking Spring quadrangle, exposures of Triassic sandstone dip southward and are strongly sheared, while the rocks on the crest and south slope of Laurel Ridge have prevalent northward dips.

The throw of the fault is at a maximum north of Union House, and is estimated as at least 7,000 feet. This figure is based chiefly on the calculated thickness of westward-dipping Triassic sediments that are truncated by the fault from the west end of Laurel Ridge to the conglomerat area north of Union House. West of the south end of the ridge of Cambrian quartzite, the fault trends away from the Triassic border and passes northwestward into Paleozoic rocks. It is possible that a fault of smaller displacement follows the Triassic border westward as far as Kleinfeltersvil yond there, in the Richland quadrangle, the contact is interpreted as an conformity. Eastward, the fault trace is at the foot of the steep slope Precambrian rocks to within 1.1 miles northeast of Union House, where lies in a depression between a hill of Precambrian rocks and a knoll of iassic conglomerate. East of there for more than a mile the fault has en drawn several hundred feet south of the steep slope. This is based on e presence of an unmistakable outcrop of Precambrian granitic gneiss out 200 feet south of the telephone line where it crosses the road from ainsport to Texter Mission. Also, no trace of Triassic float has been und north of the indicated position of the fault on the map.

North of Blainsport a fault that branches southeastward from the ain border fault repeats the conglomerate of Laurel Ridge. The maximum row exceeds 1000 feet, downthrow on the south side, displacement creases gradually eastward. Near the eastern edge of the quadrangle this ult is joined by a short fault with downthrow on the north side. From is place eastward, in the adjoining Sinking Spring quadrangle, the fault ong the south foot of Laurel Ridge has downthrow on the north side.

A fault with a probable maximum displacement of at least several ndred feet begins about three-fourths mile southwest of Cocalico, trends utheastward and passes south of Kline Hill and out of the quadrangle ar its southeast corner. The fault produces a lateral displacement of veral hundred feet in the largest diabase dike. An east-west fault north f Kline Hill is inferred to account for the truncation and discordant trikes of conglomerate units. Downthrow is apparently on the north side.

A set of four generally parallel faults with northeasterly strike uts the Furnace Hills area south of Kline Hill and causes offset of everal conglomerate bodies that have been mapped. Throughout that area lickensided rock is particularly abundant.

Several minor faults are inferred in the vicinity of Union House o account for the discordant strikes of locally developed conglomerate. he locations of the faults are not accurately known, but they are believed o follow depressions that are covered by Recent alluvium. Small faults hat offset traceable horizons are found west and south of Cocalico and orthwest of Blainsport.

The small area of Martinsburg shale at the foot of South Mountain orth of Cocalico may be a high-standing part of the floor on which the riassic sediments were deposited. The close association of shale conglomrate supports this interpretation. On the other hand, it may be entirely ounded by faults, though the one separating it from the Triassic must be f a smaller order of magnitude than the border fault that separates it rom South Mountain.

QUATERNARY

Talus composed of angular blocks of Cambrian and Precambrian rocks cover the steep slopes of South Mountain and obscure the contact of Triassic and older rocks. In addition, talus-like material of smaller dimensions extends over widespread areas of relatively gentle slope and i stream valleys. The largest such deposit is in the valley of Cocalico Creek, where it extends southward for more than a mile beyond the mouth of the deep ravine. Its average width is more than 0.3 mile, but exceeds more than one-half mile at some places, though there are "islands" in whi the underlying Triassic rocks are exposed. At the west end of Laurel Rid a broad talus-like deposit has the topographic form of an alluvial fan of very gentle slope. Recent alluvium is also widespread in the stream vall immediately south of South Mountain.

These deposits consist of highly angular fragments of Precambri rocks and Cambrian quartzite, ranging in size from a few inches to a foot or more in diameter. The size of the fragments decreases with increasing distance from their source but they show no indications of having been water-worn.

MINERAL RESOURCES

MICA

In view of the importance of muscovite in industry and the federal ernment's subsidy program, maps and brief descriptions are given here of two mica prospects on South Mountain.

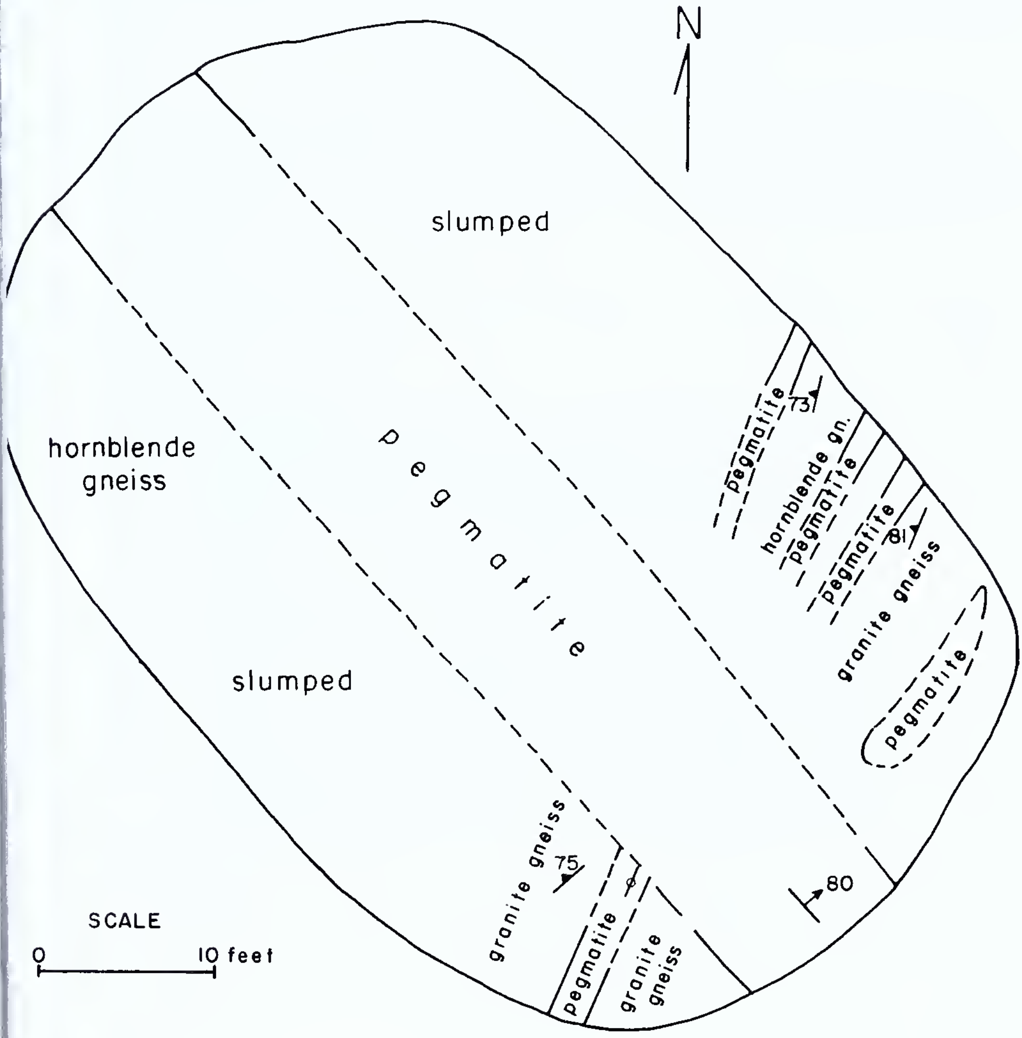


Figure 26. Plan of upper abandoned pegmatite mine on south side of South Mountain, Lancaster County near the Lancaster-Lebanon County line.

An old mine said to be operating about fifty years ago, is loca along the Lebanon-Lancaster County line about half a mile northeast of th Cocalico-South Mountain School road. The country rock here is hornblende gneiss and granite gneiss and strikes N15-56°E and dips 73-81°NW (See Fig 26). The pegmatite dike is approximately 10 feet wide and strikes N42°W and dips about 80°NE. Very little of the dike itself is visible as weath ing has almost completely rotted it at the exposed surface. As shown in the accompanying sketch (Figure 27A.), the dike does not reach the surfac and was probably found at some point now midway in the pit.

Mining operations have resulted in a pit approximately 60 feet long by 25 feet wide by 25 feet deep (Figure 27B.). The pegmatite dike r nearly lengthwise through the middle of it. No commercial muscovite was found by the writer in situ in the dike but numerous pieces of ruled, da spotted muscovite were found in a nearby dump. None could be considered first grade muscovite, even though some of the pieces were 3-4 inches in diameter.

The dike itself, so far as could be determined, contains quartz and alkali feldspar crystals several inches long and clumps of biotite la a few inches long, but generally 1/2 inch long. Very little muscovite wa found in place. No zoning was noted. Both the dike and country rock are so rotten from weathering that they can be broken in the fingers.

The second mine (Walters Mine) that has been worked for muscovi is located about half a mile southwest of the above-mentioned one and is about 200 feet above the Triassic lowland to the south. It was operated 1951 by a Mr. Hess of Ephrata and some small shipments were made. At the time of the writer's visits, the chief workings included an open pit abou 25 feet long, 15 feet wide and 15 feet deep, and an inclined adit about 4 feet long which followed the dike to the northwest (Figure 28). It desce at an angle of 29° for the first 32 feet, than flattened out for the remainder. At the time of writing, the adit and much of the open pit are slumped in.

The country rock here is granite gneiss which strikes N15°E and dips 43°NW. It is soft and rotten due to weathering, and in places thin films of manganese oxides have formed along the well-developed foliation planes. The pegmatite dike has an average width of about 8 feet, but the width varies somewhat owing to its irregular walls. It trends N35°W and dips 78°NE in the open pit working and veers to N53°W in the adit. About 8 feet within the entrance to the adit the dike is displaced 7 feet along a fault which strikes N75°E and varies in dip from 64°NW to 85°SE. The hanging wall has moved down from NE to SW (See Figure 29). Slickensides the fault plane pitch 30° down to the southwest. The dike shows marked zoning with a core of quartz and muscovite about 3 feet thick and an oute zone of pink microcline, perthite, and a little biotite. The core is mos evident at the entrance to the adit, but continues intermittently to the end as shown in Figure 29. Muscovite occurs in fairly numerous books in quartz core. Most of that still visible was two to three inches in diame and free from rulings or intergrowths with biotite.

The dike thins both to the southeast and northwest along the st

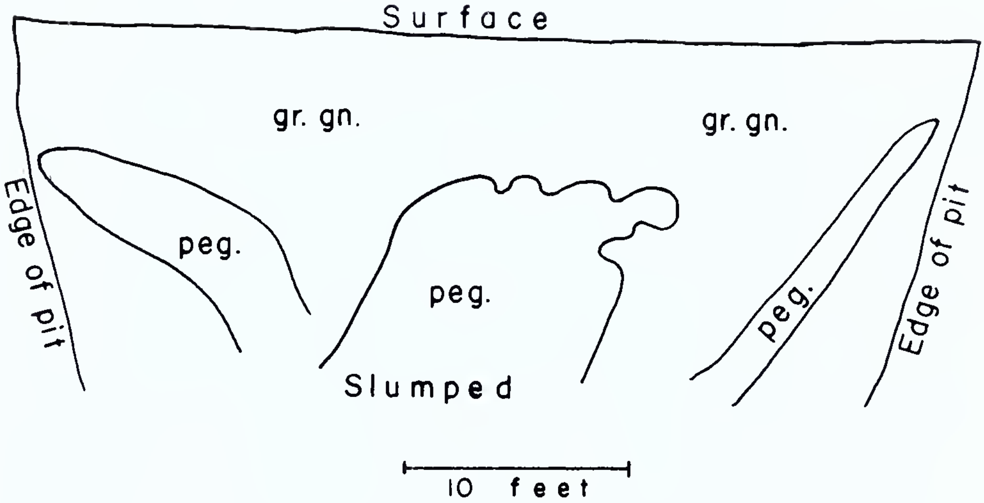


Figure 27A. Sketch of souteast face of upper abandoned pegmatite pit on south side of South Mountain, Lancaster County. Foliation is almost parallel to the pit face.

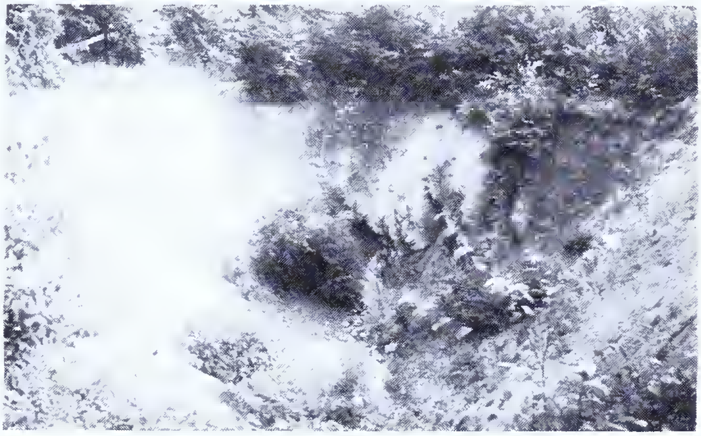


Figure 27B. Photo of same pit face. Main pegmatite dike is in right background.

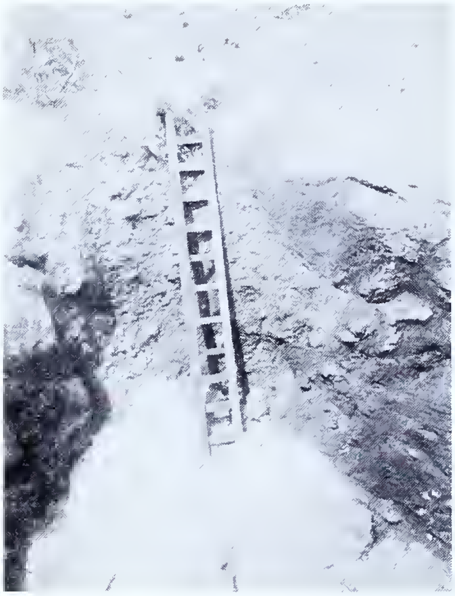


Figure 28A. Pegmatite in southeast end of pit in lower pegmatite mine. Pegmatite is light gray material under most of ladder. Very light gray is slump at bottom, and dark gray is granite gneiss.

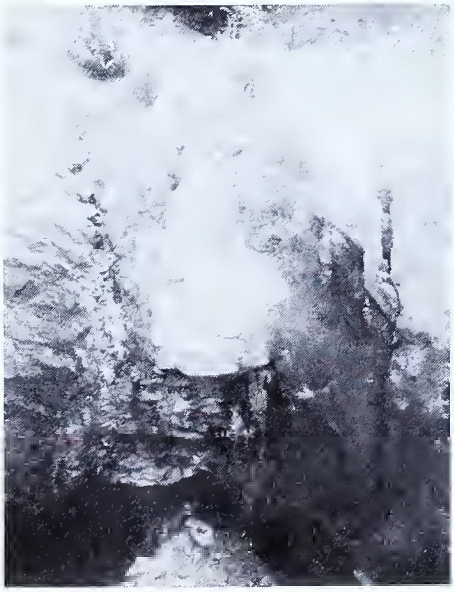


Figure 28B. Pegmatite in northwest end of open pit in lower pegmatite mine. Quartz-muscovite core is the nearly white material in the center surrounded by medium gray alkali feldspar.

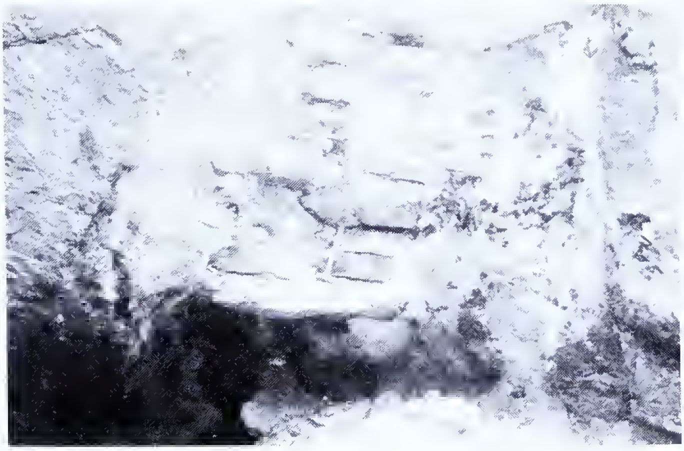


Figure 28C. Closeup of pegmatite in northwest end of open pit in lower pegmatite mine on south side of South Mountain, Lancaster Co. Hammer is resting on quartz-muscovite core.

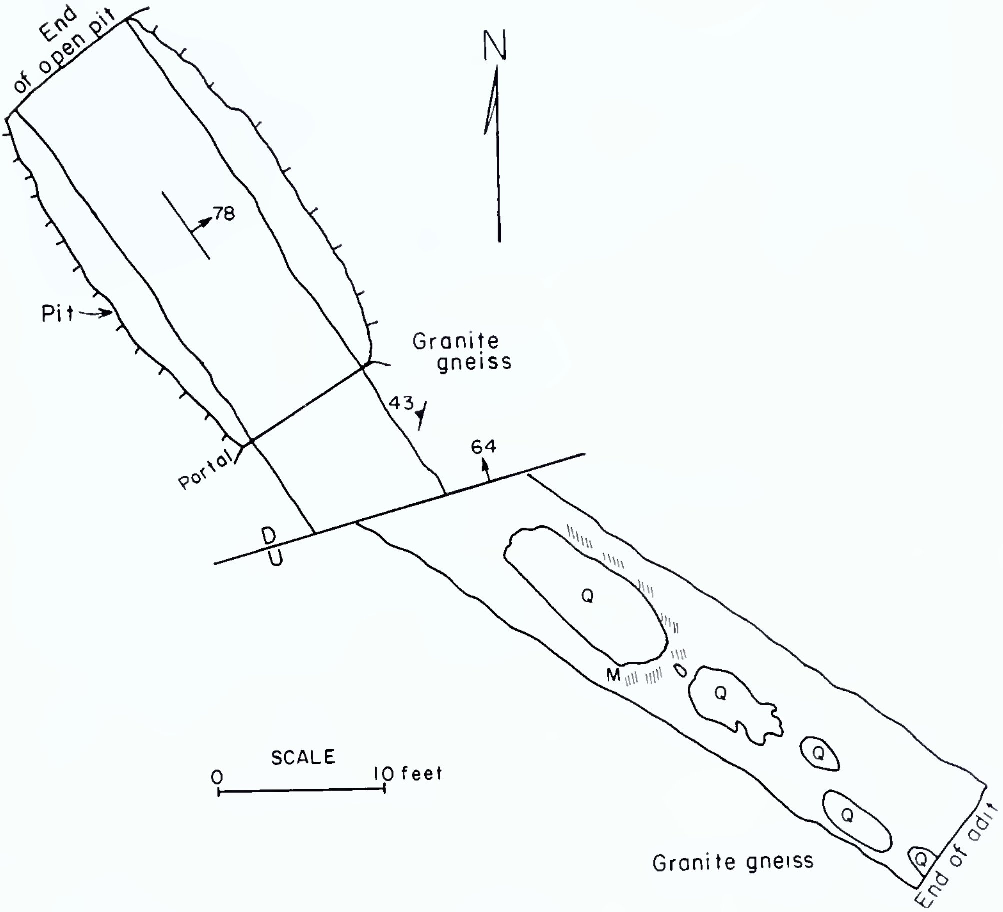


Figure 29. Plan of pegmatite dike in lower pegmatite mine on the south side of South Mountain, Lancaster County.

The dike thins both to the southeast and northwest along the strike. A trench excavated about 80 feet along the strike to the southeast uncovered only a barren foot-thick dike and one excavated across the strike about 100 feet northwest of the main pit uncovered barren pegmatite only 6 inches thick. About 600 feet to the southeast along the strike of the dike a small amount of "bull" quartz occurs in the float, but this is not necessarily part of the main dike.

HIGH CALCIUM LIMESTONE

The Annville Limestone is the only high-calcium limestone presen in the Womelsdorf quadrangle. This formation reaches a maximum thickness of 250 feet in the Lebanon Valley and averages 94 to 98.5% calcium carbonate. The Annville limestone is being quarried for flux stone, agricultura limestone, filler material, aggregate, roadstone, railroad ballast, and as a stone that is used to enrich cement rock. Chemical analyses published for the Annville limestone satisfy the requirements for cement limestone, flux stone, agricultural limestone, and in some cases, general chemical uses, filler, and lime.

The major belt of the Annville Formation is located west of Womelsdorf in Lebanon County but an area in Berks County between Millards Quarry Pond at Millardsville and Womelsdorf , underlain by Annville, merits further investigation. Figure 30 shows this area in a gray shaded pattern The author feels that a drilling program is warranted in the western part of the shaded area in Figure 30 where the Annville appears to be quite thick and of good quality. Analyses of surface exposures from this area appear in Gray (1951).

GROUND WATER

The ground-water resources of the Womelsdorf quadrangle are largely dependent on rock type and since many rock types are present within this quadrangle, ground-water occurrence and availability are varied.

A recent report on the hydrogeology of the carbonate rocks of the Lebanon Valley (Meisler, 1963) does not include the Womelsdorf quadrangle but does include the area immediately adjacent this quadrangle to the west. It is this author's belief that in general the quantitative information gained by Meisler in the Lebanon Valley to the west is applicable to the Womelsdorf area. A summary of his conclusions is as follows.

In general, the most reliable sources of ground-water within the carbonate rocks are the Schaefferstown and Millbach Formations of the Conococheague Group, and the Stonehenge and Ontelaunee Formations of the Beekmantown Group. The least reliable sources are the Snitz Creek Formation of the Conococheague Group, the Epler Formation of the Beekmantown Group, and the Hershey Limestone.

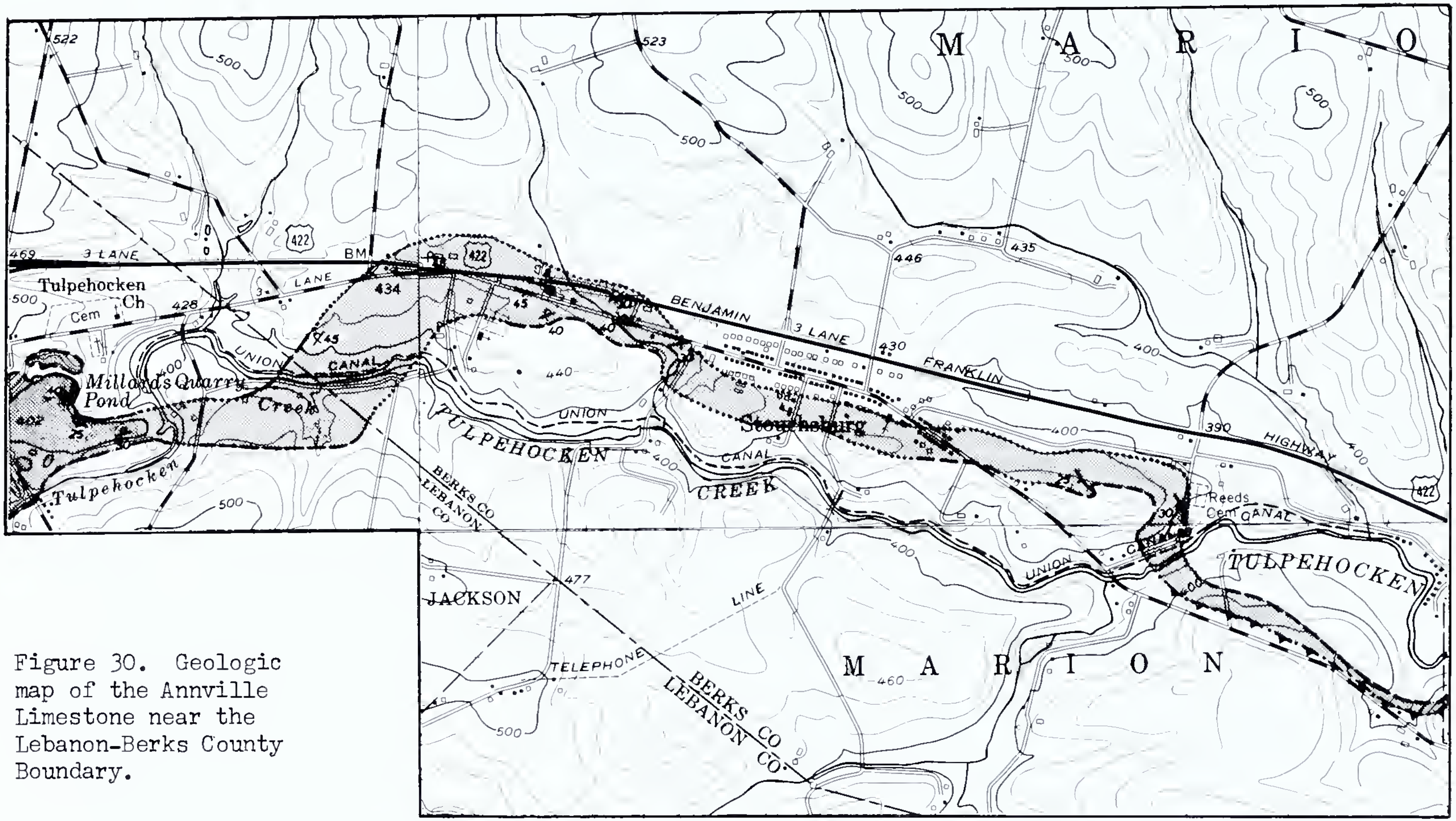


Figure 30. Geologic map of the Annville Limestone near the Lebanon-Berks County Boundary.

Meisler found that the Schaefferstown and Millbach Formations had the highest yields of any strata in the Conococheague Group. Specific capacities of 11 wells pumped ranged from 0.01 to 300; the mean was 110, and the median was 100. Seven of these 11 wells had specific capacities of over 90.

Specific capacities of 16 wells pumped in the predominantly limestone Stonehenge Formation of the Beekmantown Group ranged from 0.15 to 250. The mean specific capacity was 46 and the median was 9.3. Six of the 16 wells had specific capacities of more than 50 and two of these had specific capacities of more than 100.

Specific capacities of wells pumped in the Buffalo Springs, Snitz Creek, Richland and Epler Formations were consistently low. The median specific capacities of these formations were 3.2, 1.4, 3.5 and 3.2, respectively.

Insufficient data are available for the Rickenbach and Ontelaunee Formations. Of the six wells Meisler tested, however, these formations had high specific capacities.

The Annville and Myerstown Limestones underlie an extremely small area of the Womelsdorf quadrangle and very little data are available. Of only three wells pumped in these formations, the results ranged from specific capacities of 1.6 to 12.

Meisler found that the Hershey Limestone yielded small supplies of water to wells and was probably the least reliable source of ground water in the carbonate rocks.

No test data are available for the Martinsburg, Tomstown, Hardyston, or the igneous rock formations. With the exception of the Tomstown Formation, the water bearing characteristics of these rocks are poor. The Triassic red shales, sandstones and quartz conglomerates are also moderate to poor yielders of ground water.

REFERENCES

mery, R. W. and others (1960), *Aeromagnetic Map of the Womelsdorf quadrangle, Lebanon, Lancaster, and Berks Counties, Pa.*, U. S. G. S. GP 239, scale 1:24,000, C.I. 50 gammas.

kwalter, T. V. (1953), *Origin and field relations of the Pochuck gneiss, Berks County, Pennsylvania*, Proc. Pa. Acad. Sci., Vol. 27.

—————— (1958), *Granitization in the Reading Hills, Berks County, Pennsylvania*, Proc. Pa. Acad. Sci., Vol. 32, pp. 133-139.

—————— (1959), *Geology of the Precambrian rocks and Hardyston Formation of the Boyertown quadrangle*, Pa. Geol. Survey, 4th ser., Geol. Atlas 197.

ud, P. E. Jr. (1942), *Notes on Stromatolites*, American Journal of Science, Vol. 240, No. 5, pp. 363-379.

nvilliers, E. (1883), *The Geology of the South Mountain and the Reading Hills, Pennsylvania*, Ph. D. Thesis, University of Pittsburgh.

—————— (1887), *Report on the iron ore mines and limestone quarries of the Cumberland-Lebanon Valley, Pennsylvania*, 2nd Geological Survey of Pennsylvania, Ann. Rept. 1886, Part A.

on, H. N. (1912), *The Geology of the South Mountain and the Reading Hills, Pennsylvania*, Ph. D. Thesis, University of Pittsburgh.

ser, D. M. (1937), *Replacement of Hardyston quartzite by jasper*, Proc. Pa. Acad. Sci., Vol. 11, pp. 57-61.

edman, Gerald (1960), *Chemical analyses of rocks with the petrographic microscope*, Amer. Mineralogist, Vol. 45, pp. 69-78.

yer, A. R. and others (1958), *Geology and Mineral Resources of the Lebanon Quadrangle, Pennsylvania*, Penna. Geol. Survey, 4th ser., Atlas 167C.

ddard, E. N. and others (1951), *Rock-Color Chart*, Geol. Society of America, N. Y., N. Y.

rai, Masao (1951), *Petrological studies on plagioclase twins*, Amer. Mineralogist, Vol. 36, pp. 884-901.

ay, Carlyle and others (1958), *Geology and Mineral Resources of the Richland Quadrangle, Pennsylvania*, Penna. Geol. Survey, 4th ser., Atlas 167D.

Gray, Carlyle (1951), Preliminary Report on Certain Limestones and Dolo of Berks County, Pennsylvania, Pa. Geological Survey, 4th ser Progress Report 136, 85 p.

Hague, J. M., Baum, J. L., Herrmann, L. A., and Pickering, R. J. (1956), Geology and structure of the Franklin-Sterling area, New Jerse Geol. Soc. Am. Bull., Vol. 67, pp. 436-474.

Heinrich, E. Wm. (1956), Microscopic Petrography, McGraw-Hill Book Co., New York

Hobson, J. P. Jr. (1957), Lower Ordovician (Beekmantown) Succession in Berks County, Pennsylvania, A. A. P. G. Bulletin, Vol. 41, No. pp. 2710-2722.

__________ (1963), Stratigraphy of the Beekmantown Group in Southeastern Pennsylvania, Penna. Geol. Survey, 4th ser., Gen. Geol. Rept. G-37, p. 331.

Hotz, P. E. (1953), Magnetite deposits of the Sterling Lake, N. Y.-Ringwo New Jersey area, U. S. Geol. Survey Bull. 995-F, pp. 201-254.

Keith, A. (1894), Harpers Ferry, W. Va., U. S. Geol. Survey, Folio No. 1 p. 3.

Landes, K. K. (1933), Origin and classification of pegmatites, Am. Minera ogist, Vol. 18, no. 2, pp. 33-56, no. 3, pp. 95-103.

Meisler, Harold (1963), Hydrogeology of the Carbonate Rocks of the Lebano Valley, Pennsylvania, Pa. Geol. Survey, 4th ser., Bulletin W-18 81 p.

Miller, B. L. (1941), Geology and geography of Lehigh County, Pennsylvani Pa. Geol. Survey, 4th ser., Bull. C 39.

Miyashiro, Akiho (1961), Evolution of metamorphic belts, Jour. Petrology, Vol. 2, no. 2, no. 3, pp. 277-311.

Moorhouse, W. W. (1959), The Study of Rocks in Thin Section, Harper & Bro New York.

Prime, Frederick (1883), The geology of Lehigh and Northampton Counties, 2nd Geological Survey of Pennsylvania, P.R. D3, Vol. I, p. 54.

Prouty, C. E. (1959), The Annville, Myerstown, and Hershey Formations of Pennsylvania, Pa. Geol. Survey, 4th ser., Bulletin G 31, 47 p.

Rogers, H. D., The Geology of Pennsylvania, First Pa. Geol. Survey, Vol. p. 93, 202.

Sims, P. K. (1958), Geology and magnetite deposits of Dover District, Morr County, New Jersey, U. S. Geol. Survey, Prof. Paper 287.

tose, G. W. (1906), The Sedimentary Rocks of South Mountain, Pennsylvania, Jour. of Geology, Vol. 14, p. 201.

———— (1908), The Cambro-Ordovician Limestones of the Appalachian Valley in Southern Pennsylvania, Jour. of Geology, Vol. 16, p.698.

tose, G. W. and Jonas, A. I. (1935), Highlands near Reading, Pennsylvania; an erosional remnant of a great overthrust sheet, Bull. Geol. Soc. Am., Vol. 46, pp. 757 - 780.

urner, F. J. (1951), Observations on twinning of plagioclase in metamorphic rocks, Amer. Mineralogist, Vol. 36, pp. 581 - 589.

herry, E. T. (1909), Middle and Lower Cambrian stratigraphy of eastern Pennsylvania, Science, Vol. 30, p. 416.

ilkens, Hans (1955), Notes on the geology of the Reading Hills, the Hardyston quartzite in Berks County, Pa., Pa. Acad. Sci. Proc., Vol. 29, pp. 193-194.

ilson, J. L. (1952), Upper Cambrian stratigraphy in the Central Appalachians, Bull. Geol. Soc. Am., Vol. 63, pp. 275-322.

APPENDIX

STRATIGRAPHIC SECTIONS

Wherever possible the sections described below were measured directl on the outcrop with a 6-foot tape. Otherwise they were measured by the compass and tape traverse method, and the unit thicknesses were calculated trigonometrically. Although the writer feels that the thickness measurements are as accurate as possible under the circumstances, any one section may be a few feet in error.

The color terms used are taken from the Rock-Color Chart (Goddard and others, 1948). Color names are used in conjunction with the numerical portion. Characteristics which are distinctive for each formation are underlined in the sections.

A short summary of the principal features of the section which presents a brief over-all view of the section unencumbered by the details may be found in a preceding chapter.

Locality 1. -- Buffalo Springs, Pa.

The following reference section of the Buffalo Springs Formation was asured along an old trolley line about .7 of a mile southeast of the llage of Buffalo Springs, Heidelburg Twp., Lebanon County, Pa. This posure is located at Lat. 40°17'00" and Long. 76°19'37" in the Richland adrangle. The upper part is continuously exposed and illustrates the aracteristic lithology of the formation.

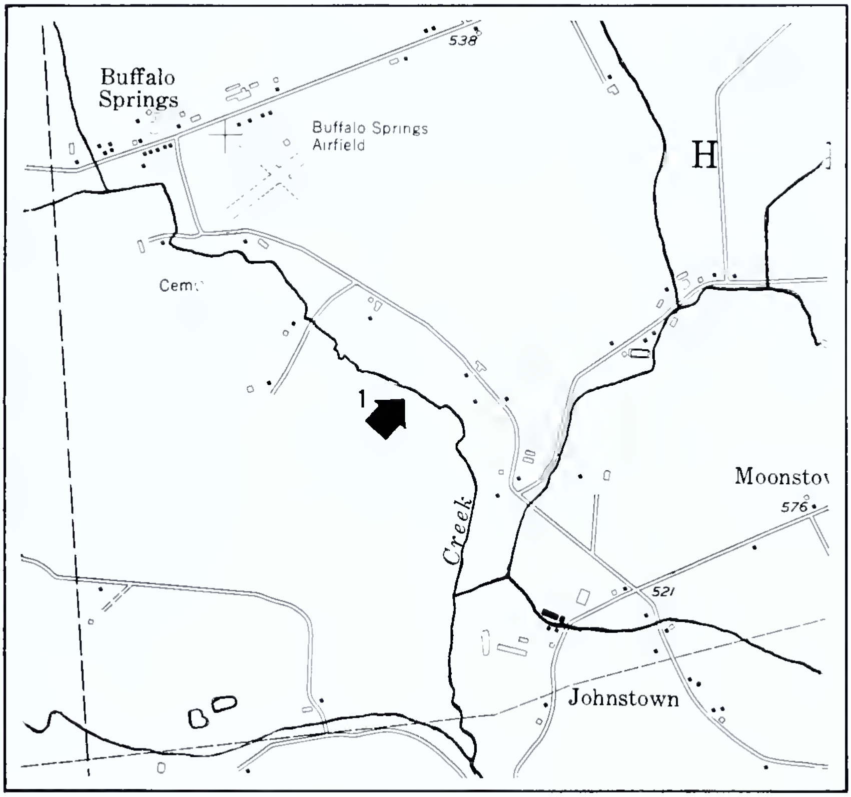


Figure 31. Location map of Locality 1.

Unit		Unit Thickness (feet)	Cumulative Thickness (feet)
Snitz Creek Formation			
1.	Limestone and dolomite interbedded; limestone is medium gray, laminated; dolomite is medium to medium dark gray, oolitic, weathering light olive gray; unit 1 represents the exposed base of the overlying Snitz Creek Formation.	6	6
Buffalo Springs Formation			
2.	Limestone; poorly exposed; light-gray to medium-light-gray to pinkish-gray; finely crystalline; numerous cryptozoons in float.	127	133
3.	Limestone; light- to pinkish-gray; mottled; finely crystalline; silty laminations; cryptozoons.	10	143
4.	Limestone; light-gray to pale-pink; laminated; beds 2 inches to 1 foot thick; finely crystalline.	8	151
5.	Limestone; light- to pinkish-gray; finely crystalline; laminated; beds 2 inches to 1.5 feet thick; dolomite interbeds; weathering yellowish-gray.	15	166
6.	Limestone; medium-dark- to pinkish-gray; finely crystalline; mottled; laminated; thick-bedded.	17	183
7.	Limestone; light-gray to pale-red-purple; 1/4-inch to 1/2-inch dolomite interbeds; finely crystalline; laminated; small pyrite crystals.	28	211
8.	Limestone; light-gray to pale-red-purple; most light-gray; finely crystalline; laminated.	3	214
9.	Limestone; light-gray to pale-red-purple; mottled; finely crystalline; laminated; beds 2 inches to 6 inches thick; weathering yellowish-gray; some beds completely leached; light-brown in color showing original laminations.	33	247
		Total	247

Locality 2. -- Cornwall Railroad, Cornwall, Pa.

A reference section for the Snitz Creek Formation may be found along e Cornwall railroad about one-half mile south of Midway Church, West rnwall Township, Lebanon County, at Lat. 40°18'00" and Long. 76°24'40" in e Lebanon quadrangle. The top and the bottom are not exposed at this te, but this section illustrates the characteristic lithology.

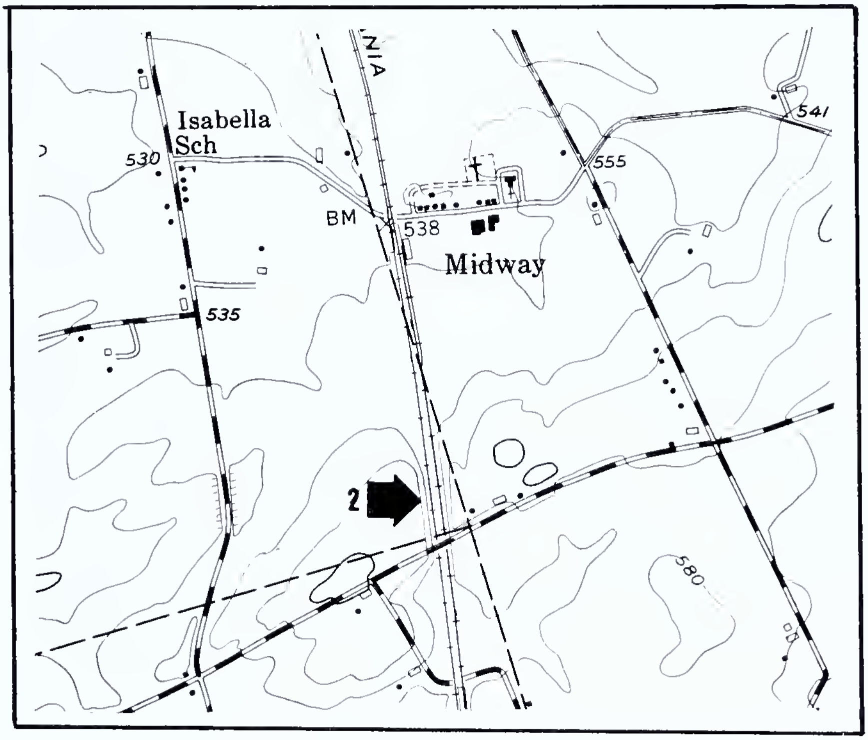


Figure 32. Location map of Locality 2.

itz Creek Formation

Unit		Unit Thickness (feet)	Cumulative Thickness (feet)
1.	Dolomite; sandy; cross-bedded; medium-light-gray; weathering yellowish gray; beds 1 foot to 2 feet thick; finely crystalline; "floating" sand grains; 3-inch bed of silty limestone at base of unit.	5	5
2.	Limestone; medium-gray; silty laminae; weathering medium-light-gray; medium to coarsely crystalline.	4	9

3.	Dolomite; medium-gray; laminated; weathering yellowish gray; finely crystalline.	6	15
4.	Dolomite; sandy; laminated; medium-light-gray; finely crystalline; weathers moderate-yellow-brown.	3	18
5.	Dolomite; medium-gray; finely crystalline; weathering yellowish gray; laminated at base of unit.	6	24
6.	Limestone; light- to medium-gray; mottled silty laminations.	1	25
7.	Dolomite; medium-gray to medium-light-gray; laminated; weathers light olive gray; finely crystalline; beds 6 inches to 2 feet thick.	5	30
8.	Limestone; medium-gray; silty laminated.	1	31
9.	Dolomite; laminated; dark-gray chert; finely crystalline; weathers yellowish-gray.	2.5	33.5
10.	Limestone; medium- to medium-dark-gray; finely crystalline; silty laminations; cherty.	2.5	36
11.	Dolomite; medium-dark- to dark-gray; finely crystalline; laminated; weathers light olive gray; thick-bedded limy beds near base of unit.	26	62
		Total	62

Locality 3. -- Sheridan, Pa.

A reference section for the Millbach Formation is located in a small
arry about 3/4-mile south of Sheridan and a mile northeast of Millbach,
the south side of Mill Creek. This quarry is in Millcreek Township,
banon County, at Lat. 40°20'46" and Long. 76°13'53" in the Womelsdorf
adrangle. Even though the upper and lower contacts of the formation are
t exposed in the quarry, it does contain some of the best examples of the
fferent varities of cryptozoon structures that were found in this valley
d demonstrates the characteristic lithology of the entire formation with
e exception of the sandstones near the top

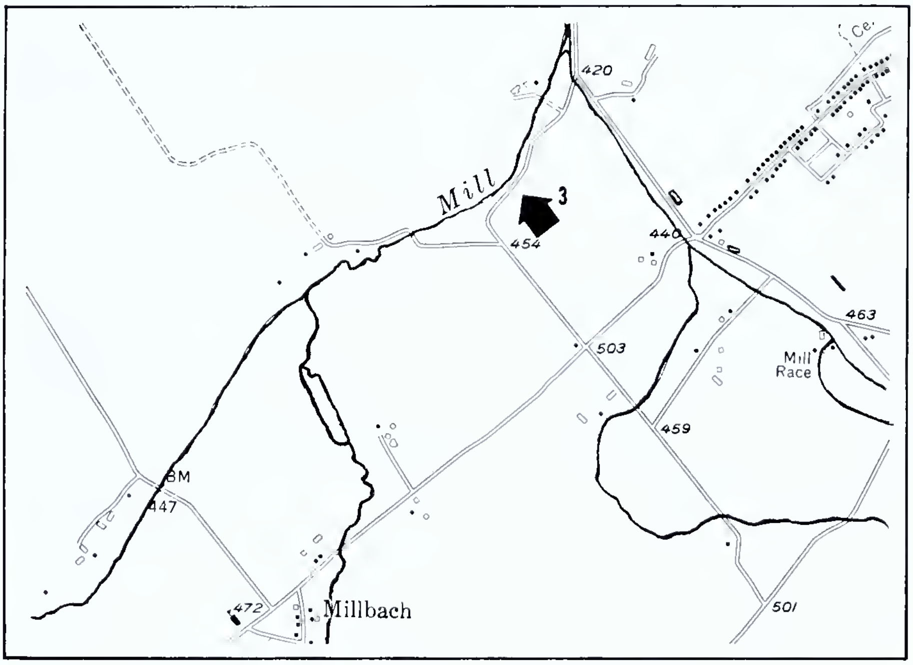


Figure 33. Location map of Locality 3.

	Unit Thickness (feet)	Cumulative Thickness (feet)
llbach Formation		
Unit		
1. Limestone; pale-red-purple to light-gray; laminated; finely crystalline.	5	5
2. Limestone; dolomitic; finely crystalline; light-gray to pale-red-purple; cryptozoons 4 inches across head; thick-bedded; laminated; small (2 inches) cryptozoons at base of unit.	9	14

3.	Limestone; algal; cryptozoons; medium- to light-gray; oolitic at base of unit.	4	18
4.	Limestone; medium-gray; finely crystalline; laminated; cryptozoons at base of unit.	5	23
5.	Dolomite; some limestone beds; dolomite is light gray; finely crystalline; limestone is light gray; silty laminations; brecciated.	7	30
6.	Limestone; light-gray to pale-red purple; laminated weathers light olive gray; finely crystalline; thick-bedded; faint oolites cryptozoons 5 inches across in center of unit; laminae weather pale yellow orange in part; mottled.	27	57
7.	Limestone; same as above with the exception of very little pale-red-purple color.	8	65
8.	Dolomite; medium-gray; weathers light olive gray; grades into light-gray limestone that is oolitic; grades into limestone and dolomite in one-half inch alternating beds; and again grades into dolomite.	5	70
9.	Limestone; light- to medium-gray; several beds of pale-red-purple limestone; cryptozoons in the pale-red-purple limestone beds; some beds weather yellowish gray.	13	83
10.	Limestone; with dolomite interbeds; beds of limestone are 2 to 3 feet thick; beds of dolomite are 1 to 1.5 feet thick; dolomite is finely crystalline; laminated; weathers yellowish gray; limestone is light gray to pale red purple; mainly pale red purple; oolitic; laminated; numerous cryptozoons in the pale-red-purple limestone beds in this unit.	29	112
		Total	112

Locality 4. -- Richland Pa.

To obtain an almost complete reference section of the Richland rmation, it was necessary to measure two exposures. The first exposure () is along the Reading Railroad tracks about 1/4 mile east of Richland Lat. 40°21'38" and Long. 76°15'00" in the Richland quadrangle. The top d part of the middle of the formation are exposed. The second exposure () which includes the entire base of the formation is located along the ad immediately west of Sheridan at Lat 40°21'32" and Long. 76°13'35" in e Womelsdorf quadrangle.

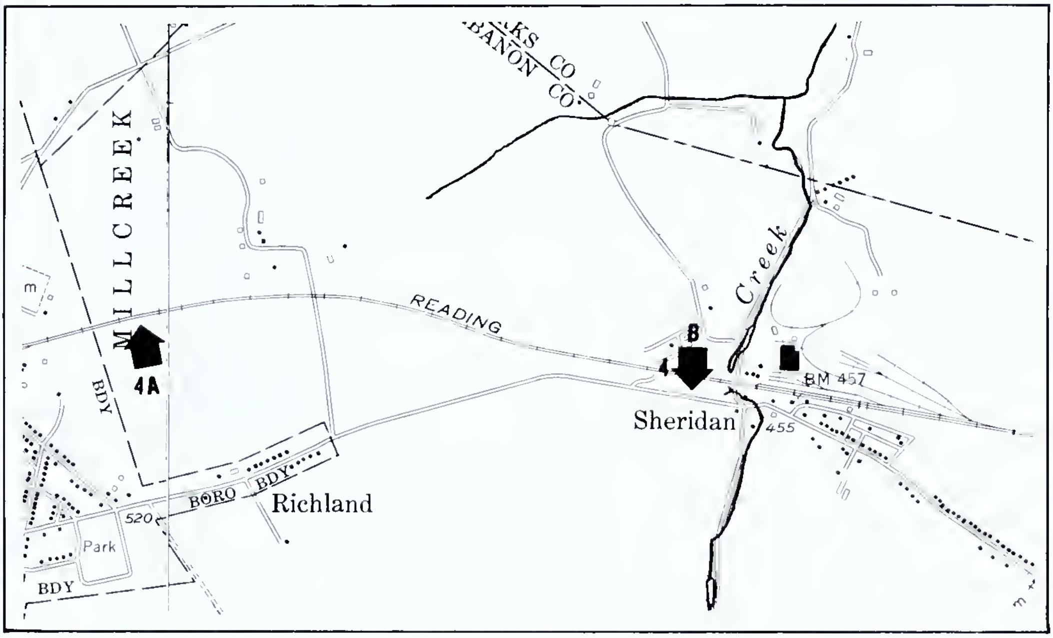


Figure 34. Location map of Locality 4.

	Unit Thickness (feet)	Cumulative Thickness (feet)
chland Formation (Upper)		
Unit		
1. Dolomite; weathers yellow gray; no sandy laminations; broken up; probably conglomeratic; silty laminations; shaly at top.	2	2
2. Dolomite; weathers yellow gray; medium crystalline; medium-gray; thin silty laminations.	.5	2.5

3.	Dolomite; alternating bands of dark-gray and light-gray; medium crystalline; weathering yellow gray and medium gray; lutite; interbeds of dolomite and limestone; dolomite bands up to 2" thick, limestone up to 1/2" thick.	4	6.5
4.	Dolomite, medium-light-gray, medium crystalline, limy, massive; parallel laminations near top and bottom; weathers light olive gray and looks punky.	6	12.5
5.	Dolomite, finely crystalline; weathers yellow-gray; fine silty laminations; wavy laminated in upper part.	22	34.5
6.	Dolomite; mostly covered interval but similar on opposite side of tracks as the preceding dolomite.	4.5	39
7.	Dolomite, medium- to medium-light-gray, massive, silty to shaly laminations; 1/2" - 2" apart.	8	47
8.	Dolomite, medium-gray, finely crystalline; weathers yellow gray.	2	49
9.	Dolomite; mostly covered.	3	52
10.	Dolomite, medium-gray; finely crystalline, massive; weathers yellow gray.	2	54
11.	Dolomite, medium-gray, finely crystalline; weathers yellow gray; parallel laminations 1-3" apart; laminations weather in.	11	65
12.	Dolomite; beds are not in place: weathers yellow gray; laminated.	28	93
13.	Dolomite, medium-light-gray, coarsely crystalline and finely crystalline; dark-gray chert nodules in fine crystalline dolomite; coarse beds weather light olive gray; fine crystalline beds weather yellow gray.	2.5	95.5
14.	Dolomite; mostly covered; beds dip almost vertical.	11	106.5
15.	Dolomite, medium-light-gray, coarsely crystalline, massive; weathers light-olive gray; thin irregular chert nodules.	7.5	114
16.	Dolomite, medium-gray, finely crystalline, massive; weathers yellow gray.	2	116
17.	Dolomite; covered.	1.5	117.5

18.	Dolomite, medium-gray, medium to finely crystalline; shaly laminations 1" apart; massive; weathers yellow gray.	7.5	125
19.	Dolomite; covered.	9	134
20.	Dolomite, medium-gray, finely crystalline to lutite; shaly laminations; weathers yellow gray; massive; thin limy bands with shaly laminations near base; some rounded conglomerate fragments.	9	143
21.	Dolomite; covered.	1.5	144.5
22.	Dolomite, medium-gray, finely crystalline; shaly laminations; some conglomerate.	4.5	149
23.	Dolomite, edgewise conglomerate, medium-light-gray pebbles up to 2" long; 2 beds of dark-gray chert, 1/4" to 4" thick; in part chert replaces matrix of conglomerate; shaly laminations 2" apart; some faint oolites in chert.	5	154
24.	Dolomite, edgewise conglomerate, medium to finely crystalline; chert.	6	160
25.	Dolomite, medium- to medium-light-gray, medium to coarsely crystalline, massive.	1.5	161.5
26.	Dolomite, medium-light-gray, very finely crystalline; faint silty laminations; weathers yellow gray.	2	163.5
27.	Dolomite; covered.	1.5	165
28.	Dolomite, medium-light-gray, finely to medium crystalline; white-quartz veins.	2.5	167.5
29.	Dolomite, medium-light-gray, medium to coarsely crystalline; discontinuous shaly laminations; conglomerate at base; weathers yellow gray.	4.5	172
30.	Dolomite, medium-gray, medium to coarsely crystalline; weathers light olive gray; banded--medium crystalline alternating with coarsely crystalline bands, locally broken into a breccia.	13.5	185.5
31.	Dolomite float; covered interval.	8	193.5
32.	Dolomite, finely to medium crystalline, laminated; weathers yellow gray; irregular lenses of oolitic dark-gray chert.	5.5	199.

33.	Dolomite; mostly covered interval.	18.5	217.5
34.	(Beginning of major uninterrupted section) Dolomite, medium-gray; weathers yellow gray; abundant dark-gray chert; in part oolitic; brecciated.	3.0	220.5
35.	Dolomite, medium-gray, finely crystalline; widely separated silty laminations--banding of light and dark color on weathered surface.	6.0	226.5
36.	Dolomite, medium-gray, lutite; weathers light olive gray; silty laminations.	1.5	228
37.	Dolomite; weathers yellow gray; closely spaced shaly laminations that are wavy and discontinuous; fine breccia in part.	13.0	241
38.	Limestone, medium-gray, medium crystalline; silty bands; weathers medium gray.	1.0	242
39.	Dolomite, medium-gray, massive-bedded, medium crystalline; weathers yellow gray; veins quartz in patches; fine shaly laminations.	4.5	246.5
40.	Dolomite, medium-gray, lutite; silty to shaly laminations that are parallel and 1" apart; cleavage well developed.	2.0	248.5
41.	Dolomite, medium-gray, dark-gray chert nodules.	0.5	249
42.	Dolomite, medium-gray, lutite; dark-gray chert bed (discontinuous).	0.5	249.5
43.	Dolomite, medium-gray, lutite to finely crystalline; very thin shaly laminations.	3.0	252.5
44.	Dolomite; with "floating" sand grains, rounded to sub-rounded and frosted; limestone pebbles in the sandy layers; dolomite is medium light gray, finely crystalline.	1.5	254
45.	Dolomite, very sandy; locally a sandstone.	0.5	254.5
46.	Dolomite, medium-gray, medium crystalline, massive-bedded; locally conglomeratic.	5.5	260
47.	Dolomite, medium-light-gray, lutite; laminations; sandy in part.	1.5	261.5

48.	Dolomite, medium-light-gray, medium to coarsely crystalline; sandy and cherty at top; shaly band in middle of unit.	2.0	263.5
49.	Dolomite, medium-light-gray, finely crystalline; shaly laminations; some conglomerate.	2.0	265.5
50.	Dolomite, medium-gray, lutite; lenses and bands of dark-gray chert; chert grades into sand.	2.0	267.5
51.	Dolomite, medium-gray, finely crystalline; sandy laminations; graded bedding, top to the west.	3.0	270.5
52.	Dolomite, medium-light-gray, medium crystalline; cherty at top of unit; weathers light olive gray; silty and shaly laminations.	1.5	272
53.	Dolomite, medium-gray, lutite; shaly laminations, regular 1" to 3" apart.	2.0	274
54.	Dolomite, medium-light-gray, finely crystalline, massive chert nodules in upper part; 3" bed of oolitic chert grading into sand.	1.5	275.5
55-61.	Best-developed cycle.		
55.	Dolomite, medium-light-gray, lutite; weathers yellow gray; fine parallel laminations.	5.0	280.5
56.	Dolomite, medium-gray, lutite, limy; weathers light olive gray.	0.5	281
57.	Dolomite, medium-gray, lutite; weathers yellow gray.	0.5	281.5
58.	Limestone, medium-gray, finely crystalline, shaly and sandy; regular parallel laminations; chert lenses; lenses, pebbles and broken layers of dolomite; limestone weathers medium dark gray.	2.0	283.5
59.	Dolomite, medium-gray, lutite; light-gray chert in layers and thin lenses.	1.5	285
60.	Dolomite, shaly, medium-gray, lutite; several flat conglomerate pebbles.	2.0	287
61.	Dolomite, medium-light-gray, finely crystalline; bands of sand grains that grade into 2" bed of chert at base.	1.5	288.5
62.	Dolomite, medium-light-gray, finely crystalline; one bed weathers yellowish gray.	1.0	289.5

63.	Dolomite, medium-light-gray, finely crystalline; sandy bands; cross-bedded, tops to west; thin chert bed at base; chert associated with medium to coarsely crystalline dolomite.	2.0	291.5
64.	Dolomite, medium-gray, finely crystalline; thin shaly laminations; scattered holes on weathered surface; weathers light olive gray.	2.0	293.5
65.	Dolomite, medium-gray, medium crystalline, limy; lutite at base.	1.5	295
66.	Dolomite, medium-gray, lutite; weathers yellowish gray; regular silty laminations.	1.0	296
67.	Dolomite, fine to medium crystalline; wavy discontinuous shaly laminations; weathers light olive gray.	3.5	299.5
68.	Dolomite, medium-gray, medium crystalline; wavy shaly laminations; weathers light olive gray.	3.0	302.5
69.	Limestone, medium-dark-gray and medium-gray in alternating bands, 1/4 to 1/2 inch thick, wavy and irregular.	2.0	304.5
70.	Dolomite, medium-gray, lutite; sandy laminations and bands; weathers light olive gray.	3.0	307.5
71.	Dolomite, medium-light-gray, medium crystalline; wavy thin shaly laminations; weathers yellowish gray.	3.0	310.5
72.	Limestone, medium-dark-gray, laminated; dolomite pebbles or knots; weathers medium dark gray to dark gray; finely crystalline.	4.5	315
73.	FAULT; displacement is less than 10 feet.		
74.	Dolomite, sandy, medium- to medium-light-gray, laminated; conglomerate beds, medium to coarsely crystalline, thick-bedded; weathers light olive gray.	120	435
75.	Dolomite, medium- to medium-dark-gray, finely to coarsely crystalline, thick-bedded; weathers yellowish gray to olive gray; laminated in part; cryptozoon structures near top of unit; chert lenses near top also.	150	585

ichland Formation (Middle)

76.	Limestone, medium- to medium-dark-gray, medium crystalline, laminated, oolitic: weathers medium gray.	50	635
77.	Covered.	70	705
78.	Limestone, medium- to medium-dark-gray, laminated, dark-gray chert, oolitic, medium to coarsely crystalline.	30	735
79.	Dolomite, medium-light-gray, coarsely crystalline, laminated, thick bedded; weathers light olive gray.	40	775
80.	Dolomite and Limestone, interbedded; limestone is medium to medium light gray, medium to coarsely crystalline, laminated; thick-bedded dolomite is light to medium gray weathering light olive gray.	90	865
81.	Limestone predominately; excellent cryptozoon structures; highly deformed beds; mostly covered unit.	300-	1165

ichland Formation (Lower)

82.	Dolomite, medium-dark-gray, medium crystalline, deeply weathered; calcite and quartz veined; weathers light olive gray; good blocky fractures; massive.	2	1167
83.	Limestone, medium-dark-gray to medium-gray, finely crystalline; thin silty laminations; weathers medium gray; massive; laminations weather darker than rest of rock.	3	1170
84.	Dolomite, medium-dark-gray, medium crystalline; deeply weathered rim; oolitic; massive; calcite and quartz veined; blocky fracture.	2	1172
85.	Calcarenite, medium-gray, questionable oolites; naturally etched surface; fossil fragments or calcite fragments seem to stand out on weathered surface; massive; irregular silty laminations; medium-gray weathered surface.	8	1180
86.	Dolomite, medium-dark-gray, lutite, deeply weathered rim; regular parallel laminations; massive; 3" - 6" partings; weathers light olive gray.	2	1182

87.	Limestone; same lithology as the limestone above; definite fossil fragments can be seen.	14	1196
88.	Dolomite, medium-light-gray, finely crystalline, massive; 6" - 1' partings; vertical calcite and quartz veins; good blocky fracture; weathers light olive gray.	4	1200
89.	Limestone, medium-gray, finely crystalline; abundant dark-gray oolites; massive; silty and dolomite patches and laminations; non-oolitic lenses layers and stringers weather medium dark gray.	3	1203
90.	Limestone, medium-dark-gray, finely crystalline, massive; thin (1/4") interbeds of alternating limestone and dolomite; dolomite is pinched into miniature boudens; slightly oolitic; weathers medium gray and light olive gray.	2	1205
91.	Limestone; same lithology as that with the abundant oolites; cyclic sedimentation.	2	1207
92.	Limestone; same lithology as the thin interbedded limestone with alternating limestone, dolomite, and silty bands.	3	1210
93.	Dolomite, medium- to medium-dark-gray, lutite; vertical calcite veins; lower part has thin shaly laminations.	3	1213
94.	Limestone, medium-gray, finely crystalline; shaly bedded; deeply weathered; weathers light olive gray; weathers to paper thin, platy fragments.	2	1215
95.	Limestone, medium-gray, massive, calcilutite; good drag folds; silty vertical thin laminations; naturally etched surface; weathers medium gray and light olive gray or darker; well pronounced edgewise conglomerate at base; elongated pebbles radiate towards top of beds; beds are overturned, some oolites.	3	1218
96.	Dolomite, medium-dark-gray, finely crystalline, slabby bedded, weathers grayish-brown (5YR 3/2) to dark yellow (10YR 4/2) 1" - 5" limestone interbeds near base; oolites in limestone.	4	1222
97.	Limestone, medium-gray, massive, finely crystalline; thin silty laminations; elongated pebbles but not edgewise in position; faint oolites; weathers medium gray.	1	1223

98.	Dolomite, medium-gray, lutite; weathers light olive gray and gray brown; massive; 6" - 1' partings.	5	1228
99.	Dolomite, medium-gray, lutite to very finely crystalline; deeply weathered; shaly bedded; weathers light olive gray.	2	1230
100.	Limestone, medium-gray, calcilutute, massive; faint oolites or fossil fragments; cryptozoon structures at top of unit; cryptozoon are 1/4" in diameter; shaly interbeds at base.	5	1235
101.	Dolomite, medium-gray, lutite, massive; weathers light olive gray to gray brown; thin silty laminations at base.	7	1242
102.	Dolomite, medium-dark-gray, lutite; good blocky fracture; excellent upside down cryptozoon structures, 2" in diameter; dark-gray chert present; a thin layer of limestone also with cryptozoon; dolomite weathers light olive gray.	5	1247
103.	Dolomite, medium-gray, finely crystalline at top to lutite at base; 6" partings at top to shaly bedded at base; weathers light olive gray.	4	1251
104.	Limestone, medium crystalline; weathers medium gray; scattered pyrite; regular parallel silty laminations; faint oolites in some places.	2	1253
105.	Dolomite, medium-light-gray, very finely crystalline at base to lutite at top; 1/2" - 6" partings; massive; weathers light olive gray to gray brown.	4	1257

Section from here on is based on a calculated thickness and scattered exposures.

Section is largely covered.

106.	Dolomite, medium-gray, some parts medium-light-gray, finely crystalline to lutite, massive; 6" - 1.5' partings; vertical jointing; quartz and calcite veins abundant; thin weathered shell; no sandy beds visible; weathers light olive gray to gray brown.	36	1293
		Total	1293

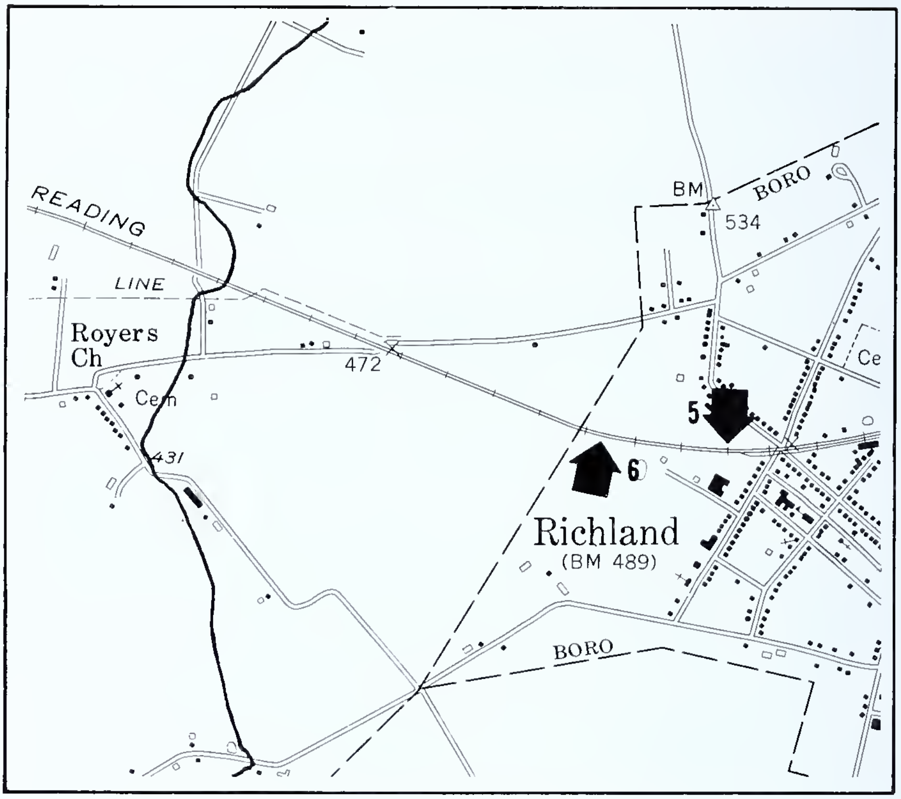


Figure 35. Location map of Localities 5 and 6.

Locality 5. -- Richland, Pa.

The following reference section of the Rickenbach Formation in Lebanon County has been measured along the Reading Railroad on the west si of the Borough of Richland, Millcreek Township, Richland quadrangle. The top but not the bottom of this formation is exposed.

	Unit Thickness (feet)	Cumulative Thickness
Epler Formation		
Limestone, light-gray, finely crystalline, massive; dolomite in small isolated masses, possible fossil fragments are numerous at top of unit; isolated masses of dolomite weather yellowish gray; limestone weathers medium gray to dark gray; bottom and top grade into dolomite.	6.0	

kenbach Formation

Unit			
1.	Dolomite, medium-light-gray, lutite, massive, faint laminations; weathers light olive gray.	2	2.0
2.	Limestone, medium-light-gray, lutite; 1" bands of silty material; bands weather dark gray; limestone weathers medium light gray.	1	3.0
3.	Dolomite, medium-light-gray, lutite; 6" - 1' partings; regular parallel laminations; rudite at top; massive; weathers light olive gray.	4.5	7.5
4.	Dolomite; same lithology as unit #3; about 5% limestone still remains; gradational contact at base.	2.5	10.0
5.	Limestone, medium-light-gray, lutite; weathers medium gray; isolated masses (probably dolomitized fossils) of dolomite in center of unit; gradational upper contact; sharp lower contact.	1.5	11.5
6.	Dolomite, medium-gray, lutite; weathers yellowish gray; no laminations; sharp basal contact.	2	13.5
7.	Limestone, medium-light-gray, dark-gray parallel streaks; quartz and calcite stringers; finely crystalline; massive; gradational lower contact; weathers medium gray; involved in a boudinage structure here.	3	16.5
8.	Dolomite; same lithology as unit #3; chert present in 3"x1" stringers or lenses; about 5% limestone.	10	26.5
9.	Dolomite, medium-gray, lutite; weathers to yellowish gray; fine parallel laminations; laminations weather darker than rest of rock; sharp basal contact.	4.5	31.0
10.	Limestone, medium-light-gray, lutite; silty laminations 3" apart; dolomitized fossil fragments (?) at top and bottom; center is least dolomitized; massive; gradational bottom.	3	34.0
11.	Dolomite; same as unit #3.	4.5	38.5
12.	Limestone, medium-light-gray, finely crystalline; weathers medium gray; dark-gray streaks; boudinage structure; sharp upper and lower contact.	1	39.5

13.	Dolomite, medium-light-gray, lutite, massive; weathers yellowish gray; strongly laminated at top; sharp top and bottom contact.	3	42.5
14.	Limestone, medium-gray, lutite, massive; weathers medium light gray; dolomitized at top and bottom, grading towards center.	2.5	45.0
15.	Dolomite, medium-gray, lutite; weathers yellowish gray; sharp upper and lower contact; regular parallel laminations.	3	48.0
16.	Dolomite; same lithology as unit #3; no chert; a little limestone.	3.5	51.5
17.	Limestone, medium-light-gray, massive; fine parallel laminations; partially dolomitized; dolomitized fossil fragments; lutite, weathers medium gray.	2.5	54.0
18.	Dolomite, medium-gray, lutite, massive; regular parallel laminations; weathers light olive gray; 6" - 8" calcite, quartz, and chert mass at base; 1" partings.	4	58.0
19.	Dolomite, medium-gray; faint parallel laminations; lutite; massive; weathers yellowish gray.	1.5	59.5
20.	Dolomite, medium-gray, lutite, massive; 1' partings; regular parallel laminations and wavy laminations; lithology partly like that at unit #3; no chert or limestone; ½" - ¼" shaly beds between 1' beds of dolomite.	6.5	66.0
21.	Dolomite, dark-gray, massive, lutite; very faint laminations; weathers yellowish gray.	1.5	67.5
22.	Dolomite, medium- to medium-dark-gray, lutite, massive; 1' - 1.5' partings; weathers light olive gray; lower 1.5' is dolomitized limestone with 5-25% limestone still present.	12.5	80.0
23.	Dolomite, medium-gray, lutite, massive; faint regular parallel laminations; weathers yellowish gray; sharp basal and upper contact.	2.5	82.5
24.	Limestone, medium-light-gray, lutite, massive; sugary appearance; weathers medium light gray to light olive gray; dolomitized and shaly upper contacts; both basal and upper contacts are sharp; regular parallel laminations.	4	86.5

25.	Dolomite, medium-dark-gray to dark-gray, lutite, massive; 1' partings; regular parallel laminations; weathers light olive gray and yellowish gray.	4.5	91.0
26.	Limestone, medium-light-gray, massive; 1' partings; finely crystalline; dolomite in nodules, masses, and stringers that weather out on surface; parallel dolomitic laminations; unit weathers yellowish gray with some medium light gray to light gray patches.	11	102.0
27.	Dolomite, medium-light-gray, massive; faintly laminated; weathers yellowish gray; dark-gray chert nodules and lenses; some oolites along bedding plane.	1	103.0
28.	Limestone; same lithology as that above; dolomitized fossil fragments; some dark-gray chert.	3.5	106.5
29.	Dolomite, medium-gray, lutite, massive; 1' - 1.5' partings; faint laminations; weathers yellowish gray; dark-gray chert patches on bedding planes just below top; stylolitic surfaces.	6.5	113.0
30.	Limestone, medium-light-gray, finely crystalline; partially dolomitized; weathers medium gray; dark-gray chert lenses near top; massive; dolomite laminations; sharp lower contact; gradational top.	8.5	124.0
31.	Dolomite, medium-dark-gray, lutite, massive; fine laminations, regular parallel; 8" - 1' partings; weathers yellowish gray.	5	129.0
32.	Limestone, medium-light-gray, finely crystalline; dolomitized at top; gradational top and bottom contact; massive; dolomite laminations; calcarenite patches; dark-gray chert nodules and lenses at base; weathers medium to medium light gray.	5	129.0
33.	Dolomite, medium-gray, lutite, massive; 1' - 2' partings; weathers yellowish gray; dark-gray chert lenses and nodules near base; regular parallel laminations.	14	143.0
34.	Limestone, medium-light-gray, weathers light gray, finely crystalline; dark-gray chert at top; regular laminations; gradational base and top; dolomite boudins; chert weathers a grayish brown to a dusky brown (5YR 3/2 - 5YR 2/2).	2	145.0

35.	Dolomite, medium-light-gray, lutite, massive; 1' - 2' partings; dark-gray chert lenses; 3" - 4" bed of chert in center of unit; chert weathers grayish brown; fine regular parallel laminations in dolomite.	16	161.0
36.	Limestone, light-gray, finely crystalline, weathers medium gray to medium light gray; rudite at top; cherty at top and middle; fossil fragments; gradational base; massive; dolomite and cherty laminations.	2	163.0
37.	Dolomite, medium- to mediumdark-gray, fine to medium crystalline; 1' - 1.5' partings; massive; silty laminations; several chert beds.	20.5	183.5
38.	Dolomite: same lithology as that at unit #3; no chert; gastropod fossil fragments present; completely dolomitized; medium to coarsely crystalline and limy.	2	185.5
39.	Dolomite, medium-light to medium-gray, lutite, massive; 6" - 1' partings; faintly laminated; massive; shallow stylolitic surfaces; weathers yellowish gray.	21	206.5
40.	Limestone, dark-gray at top, medium-gray in middle and base; lutite at top, rudite at base; cherty in middle and base; black chert lenses in middle of unit; fossil fragments; gradational top; sharp basal contact; finely laminated; weathers medium gray and yellowish gray; 2" - 6" partings; mostly dolomitized.	1.5	208.0
41.	Dolomite, medium-gray, finely laminated, lutite, massive; 1' partings; weathers yellowish gray.	6	214.0
42.	Limestone, light-gray with medium-gray streaks; mottled with grayish orange pink 5YR 7/2 at base; weathers medium light gray; silty and dolomite laminations; partially dolomitized; gradational upper contact; sharp lower contact; dark-gray chert bed near top.	2	216.0
43.	Dolomite, medium- to medium-dark-gray at base, lutite; 1' - 1.5' partings; weathers yellowish gray; fine laminations; several thin chert beds; massive.	31	247.0
44.	Dolomite, medium-gray, lutite; lenses of light-colored (light-gray) chert; fine laminations; massive; light-gray-colored chert weathers 10YR 6/4 (between a gray orange and a medium yellowish brown.)	2.5	249.5

45.	Dolomite; same lithology as that above the light-colored chert; all medium gray.	23	272.5
46.	Dolomite, medium-dark-gray, medium crystalline, massive; 1' partings; weathers light olive gray.	9.5	282.0
47.	Dolomite, medium-light-gray, lutite; fine laminations; dark- and medium-gray-banded chert lenses and dark-gray chert nodules.	3	285.0
48.	Dolomite; same lithology as unit #35; partially covered.	20.5	305.5
49.	Dolomite, medium-dark-gray, lutite, finely laminated; weathers yellowish gray; massive; beds and lenses of dark gray chert.	1.5	307.0
50.	Dolomite, medium to coarsely crystalline: partially covered.	12	319.0
51.	Dolomite, medium-gray, fine to medium crystalline, massive; sandy laminations.	4.5	323.5
52.	Dolomite, medium-dark-gray, medium to coarsely crystalline; 1' partings; massive; dolomitized at base but still limy; weathers light olive gray.	11	334.5
		Total	334.5

Locality 6. -- Richland, Pa.

A reference section for the Epler Formation in Lebanon County is located along the Reading Railroad about 0.3-mile west of the Borough of Richland, Jackson and Millcreek Townships, Richland quadrangle. Almost th entire formation is exposed along the railroad.

		Unit Thickness (feet)	Cumulative Thickness
Ontelaunee Formation (Chert horizon)			
Unit			
1.	Chert, medium-light-gray and dark-gray, mottled, weathers a dusky yellowish brown (10YR 2/2), lutite, laminated; 10" medium-light-gray dolomite in center of chert beds; massive; soil containing the chert is a redder color.	3.5	3.5
Epler Formation			
2.	Dolomite, medium-gray, medium crystalline, weathers yellowish gray; massive; not laminated; 1" partings; sharp upper contact; (N10E, 48N).	2	5.5
	Covered interval for 27' (Horizontal distance)	19	24.5
3.	Dolomite, medium-light-gray, massive; 1" partings; laminations; weathers yellowish gray; lutite; shallow stylolitic surfaces.	4	28.5
4.	Limestone, medium-gray, weathers medium light gray, lutite, massive; dolomitized fossil fragments; lower part completely dolomitized; dolomite weathers yellowish gray; no laminations; sharp upper contact (N15E, 32N).	1.5	30
	Covered interval 17' horizontal distance.	8	38
5.	Dolomite, medium-light-gray, medium crystalline; 1' partings; weathers yellowish gray; shallow stylolitic surfaces; quartz veins; faintly laminated; massive.	3.5	41.5
	Covered interval 111' horizontal distance.		

East end-Bedding strikes and dips 50N, N18E.	84	125.5
Dolomite, medium-gray, lutite, massive; 6" - 1' partings; rudite in places; 6" bed of limestone near top; dolomite weathers yellowish gray; faintly laminated; gradational base.	5.5	131
Limestone, medium-gray, massive, fucoidal, laminated; 1' partings; weathers medium light gray; lower part has hole-like structures weathered in on the surface; beds dip north.	7	138
Covered interval 883' horizontal distance.	530	668
Limestone,light-gray, finely crystalline; fine laminations; weathers medium light gray; weathers into chip-like fragments; sandy feel (calcite sand); massive; 1' partings; punky looking.	8.5	676.5
Dolomite, medium-light-gray, weathers yellowish gray, lutite; 3" - 6" partings; sharp basal contact; good blocky joint system.	3.5	680
Limestone, medium-light-gray, massive; 3" - 6" partings; weathers light gray to medium light gray; very fine dark-gray laminations; drag folds show beds to be right side up.	2.5	682.5
Dolomite grading downward into limestone, medium-light-gray, lutite; weathers yellowish gray.	.5	683
Limestone, medium-light-gray; weathers light olive gray; partially dolomitized in alternating layers; 6" partings; lutite; very fine laminations.	4	687
Dolomite, medium-gray, lutite; weathers yellowish gray; 3" - 6" partings; laminations; involved in boudinage structures.	3.5	690.5
Limestone, light-gray; weathers medium light gray; finely crystalline; very finely laminated; also involved in boudinage structures.	3	693.5
Dolomite; same lithology as above.	1	694.5
Limestone, medium-light-gray, partially dolomitized; faintly laminated; massive; sharp upper and lower contact.	3	697.5
Dolomite, medium-light-gray, finely crystalline; weathers a light olive gray; calcite joint filled spaces; massive.	1	698.5

18.	Limestone, light-gray at top, medium-light-gray at base; lutite; finely laminated at top; looks punky; base is partially dolomitized; sharp top contact; mottled at top in places.	6	704.5
19.	Dolomite, medium-light-gray, lutite; weathers yellowish gray; 2" - 1' partings; silty laminations; sharp basal contact.	3.5	708
20.	Limestone, medium-light-gray, finely crystalline; silty laminations; silty bands weather in.	.5	708.5
21.	Dolomite, medium-dark-gray, weathers yellowish gray; 1" partings; lutite; quartz and calcite coatings on joint surfaces.	2.0	710.5
22.	Limestone, medium-light-gray, finely laminated, weathers light gray at top; 1" partings; finely crystalline; steeply dipping cleavage; partially dolomitized.	2.5	712.5
23.	Dolomite; lithology same as previous dolomite; medium-gray; involved in boudinage structures.	1.0	713.5
24.	Limestone, medium-light-gray, lutite; silty laminations; draged or wavy laminations; 6" partings; weathers medium light gray; sharp upper and lower contacts.	2.5	716
25.	Dolomite, medium-light-gray, lutite; very finely laminated; weathers light olive gray; 1' partings; shallow stylolitic surfaces; highly fractured parallel to strike.	8.0	724
26.	Limestone, medium-light-gray, finely crystalline; dark-gray fine laminations; massive; weathers medium gray; lower part calcarenite; silty and dolomitic laminations; dolomite laminations weather in; limestone weathers dark-gray in places; dolomite crystals weather out on the surface.	7.5	731.5
27.	Dolomite, light-gray, lutite; 1' partings; sandy; finely laminated; massive; weathers light olive gray with dark-gray surface on sandy layers.	4.5	736
28.	Limestone, medium-light-gray, lutite; partially dolomitized; laminated; weathers light gray; massive.	2.0	738

29.	Dolomite; parallel laminations; medium-light-gray; weathers yellowish gray; lutite; massive; quartz and calcite vein fillings; sharp upper contact with truncated beds and sharp lower contact.	1.5	739.5
30.	Limestone, medium-gray, weathers medium light gray; fine parallel laminations; penecontemporaneous deformation present; calcite blebs; 3" to 6" partings; lutite.	1.5	741
31.	Dolomite, dark-gray, weathers yellowish gray; lutite; lower part limy; 6" to 1' partings; strike N20W, 11S dip.	4.0	745
32.	Limestone, medium-gray; fine parallel laminations; dolomite laminations and blobs; some dolomite layers less than 1/8"; finely crystalline; massive.	4.0	749
33.	Dolomite, dark-gray, weathers yellowish gray, lutite; calcite blobs; regular parallel laminations.	1.0	750
34.	Calcarenite, medium-gray, weathers medium light gray; cherty at base; silty laminations; regular parallel laminations; 1' partings.	5.0	755
	Concealed Interval for 42' horizontal distance. Beds strike N22W and dip 10S at west end of interval. N 5E and dip 41N at east end of interval.	19.0	774
35.	Dolomite, medium-light-gray, lutite, weathers yellowish gray; 1' - 2' partings; massive; silty laminations; quartz filled veins and pods.	10.0	784
36.	Limestone; several litho-types present: 1) medium-light-gray, finely crystalline; sugary surface; finely parallel laminae; massive; weathers medium light gray. 2) medium-light-gray, finely crystalline; streaks and blebs of dolomite; fossils (?); massive; laminated; weathers medium gray and yellowish gray. 3) light-gray; massive; parallel laminae; irregular dolomitization; finely crystalline.	11.0	795
37.	Dolomite, medium-light-gray, lutite, weathers yellowish gray, massive; lower part concealed.	4.0	799
38.	Limestone, light-gray, massive, sugary surface, laminated; $\frac{1}{2}$' - 1' partings; medium-gray weathering; high porosity.	7.0	806

39.	Dolomite, medium-light-gray, lutite, massive; 1' partings; 2' of this litho-type at top; weathers yellowish gray; next 1' is medium-gray, partially dolomitized limestone, dolomite layers and lenses, weathers yellowish gray and medium gray, finely crystalline; lower 2' are medium-dark-gray dolomite, lutite, laminated, weathers light olive gray, faint stylolitic surfaces, 2" - 3" partings.	6.0	812
40.	Limestone, medium-gray, lutite, massive, weathers medium dark gray to dark gray; partially dolomitized at base; dolomite stringers and lenses; highly folded laminae weather darker than limestone matrix.	7.0	819
41.	Dolomite, medium-light-gray, lutite; faint laminae; massive; weathers yellowish gray.	8.0	827
42.	Calcarenite, medium-gray, massive, laminated; dolomite stringers and lenses, gastropod and other fossil fragments; weathers medium light gray and yellowish gray; finely crystalline.	2.0	829
43.	Limestone, medium-gray, lutite; draged laminae; silty and dolomite laminae; weathers medium gray to medium light gray; massive; 1' and 2' partings; laminae weather dark gray.	8.0	837
44.	Dolomite; same lithology as the dolomite last described.	2.0	839
45.	Limestone, medium-light-gray, laminated; silty laminae; folded.	1.0	840
46.	Dolomite, light-gray, lutite, massive, weathers yellowish gray.	1.5	841.5
47.	Limestone, mottled light-gray to white, finely crystalline, weathers medium light gray; fossil fragments, mostly gastropods; laminated.	1.0	842.5
48.	Dolomite, light-gray, weathers yellowish gray, lutite; regular parallel laminae; massive; 1' partings; 6" marbloid bed in center of unit; 1" to 2" pale-yellow-orange (10YR 8/6)-stained shaly layer at base.	5.5	848
49.	Limestone, light-gray, finely crystalline; 85% dolomite at top; massive; dolomite stringers, lenses and blobs; weathers medium gray to light olive gray.	2.5	850.5

50.	Dolomite, medium-light-gray, lutite, massive; very finely laminated; quartz and calcite veins; weathers yellowish gray.	2.0	852.5
51.	Limestone, light-gray, finely crystalline, weathers medium light gray; partially dolomitized at top; regular parallel laminae.	2.0	854.5
52.	Dolomite, medium-light-gray, lutite, weathers light olive gray; 3" - 6" partings; very fine parallel laminations; sharp upper and lower contacts; massive; quartz and calcite veins; pyrite in some veins (disseminated).	8.0	862.5
53.	Limestone, light-gray; streaks and lenses of dolomite; fossil fragments; very irregular basal contact; massive; weathers yellowish gray and medium light gray; calcite crystals on joint surfaces.	2.0	864.5
54.	Dolomite, medium-light-gray, massive; 1' partings; lutite, fine parallel laminations that weather lighter in color than rest of rock; dolomite weathers yellowish gray; lower limestone tongues into dolomite at base.	2.0	866.5
55.	Limestone, same lithology as unit #53; fluted surface; calcite crystals on joint surfaces.	1.5	868
56.	Dolomite, medium-gray, finely crystalline, weathers yellowish gray; dark-gray chert bed; 6" - 1' partings; massive; regular parallel laminations; laminae weather darker than dolomite.	6.5	874.5
57.	Limestone, medium-gray to medium-light-gray, finely crystalline, boudins enclosed in limestone; lenses, stringers and boudins of dolomite; massive; fine dark-gray streaks.	3.0	877.5
58.	Dolomite, medium-gray, finely crystalline, weathers yellowish gray, massive; faintly laminated; calcite blobs; gradational top contact; sharp lower contact.	3.0	880.5
59.	Limestone, medium-light-gray, finely crystalline, gradational basal contact; dolomite laminations; weathers medium gray and light olive gray; massive.	3.5	884
60.	Dolomite; same lithology as unit #58; gradational upper and lower contacts.	2.0	886

61.	Limestone; wavy parallel laminations and regular parallel laminations; may be a fault at this location; beds change in dip and strike very readily; laminations weather dark gray; rock weathers medium light gray; medium-gray on fresh surface: finely crystalline; massive; 1' partings; shows good cleavage; part of unit concealed.	10.0	896
	Covered Interval.	42.0	938
62.	Limestone, light-gray, finely crystalline, massive; 6" - 1' partings; weathers medium gray; fine regular parallel laminations; fossil fragments; limestone is involved in a large drag fold; mottled in part.	13.0	951
63.	Dolomite, medium-light-gray, finely crystalline, massive; 6" - 1' partings; rudite in upper part; dark-gray chert nodules and lenses in rudite; regular parallel laminae; weathers yellowish gray at top to light olive gray at base.	7.0	958
64.	Dolomite, medium-light-gray, massive, lutite; wavy laminae, dark-gray chert; weathers light olive gray.	2.5	960.5
65.	Limestone, medium-light-gray, finely crystalline at top; 50% dolomite in elongate lobes, lenses and irregular masses at top; 6" dark-gray dolomite bed in middle of unit; lower part is light-gray; weathers medium light gray; regular parallel dark-gray streaks; very-pale-orange (10YR 8/2)-colored lenses of chert.	10.0	970.5
66.	Dolomite, medium-gray, lutite, massive; fine dark-gray regular parallel laminations; 6" partings; weathers light olive gray; limestone boudin in center of unit; limestone weathers medium light gray.	3.5	974
67.	Dolomite; same lithology as unit #64; 6" - 1' masses of dark-gray chert; distinct feature of this unit is a very fine silty or cherty layer around fragments and block-like pieces of dolomite.	7.0	981
68.	Dolomite, medium-gray, lutite, weathers yellowish gray, massive; regular parallel laminae.	2.5	983.5
69.	Limestone, light-gray, massive; dolomite in small isolated masses, possibly fossil fragments; fragments weather yellowish gray; limestone weathers medium gray to dark gray; finely crystalline; bottom and top are gradational into dolomite.	6.0	989.5
		Total	989.5

EXPLANATION

QUATERNARY

UNCONSOLIDATED DEPOSITS
Talus sediments predominate and consist of angular fragments ranging in size from coarse gravel to sand. Alluvial sediments containing stream rounded pebbles are located along many of the streams. Mud flows are present in the southern part of the quadrangle. Maximum thickness of these deposits occurs in talus sediments and is in excess of 100 feet. Bedrock is concealed where these deposits are present.

TRIASSIC

DIABASE

NEWARK GROUP GETTYSBURG FM.

SHALE CONGLOMERATE
Interbedded limestone conglomerate and quartz pebble conglomerate with shale fragments.

QUARTZ CONGLOMERATE
Interbedded coarse cobble conglomerate and red sandstone.

SANDSTONE
Fine to coarse, red and brown, quartzose sandstone with a few red shale interbeds.

ORDOVICIAN

Upper Ordovician

Om
MARTINSBURG FORMATION
Light gray to medium gray shale.

Middle Ordovician

Oh Ohl
HERSHEY LIMESTONE
Dark gray-black, thin bedded, shaly limestone. Ohl - Basal dolomite conglomerate.

Omy
MYERSTOWN LIMESTONE
Gray to light brown, thin bedded limestone, carbonaceous and very dark gray at base.

Oa
ANNVILLE LIMESTONE
Light gray, thick bedded, high-calcium limestone.

Lower Ordovician

BEEKMANTOWN GROUP

Oo
ONTELAUNEE FORMATION
Medium dark gray, thick bedded dolomite, finely to coarsely crystalline; dark gray chert beds at base.

Oe
EPLER FORMATION
Interbedded light gray limestone and dolomite; cherty; fossiliferous; numerous beds of calcarenite.

Or
RICKENBACH FORMATION
Dark gray dolomite; cherty; sandy and laminated.

Os
STONEHENGE FORMATION
Medium to light gray limestone; cherty, numerous thin shaly beds and laminations; fossiliferous; edgewise conglomerate beds present.

CAMBRIAN

Upper Cambrian

CONOCOCHEAGUE GROUP

Cr
RICHLAND FORMATION
Medium gray dolomite; cherty; oolitic; sandy; some edgewise conglomerate beds.

Cm
MILLBACH FORMATION
Interbedded light gray to pinkish gray limestone and dolomite; laminated; oolitic, cryptozoon reefs.

Csc
SNITZ CREEK FORMATION
Medium gray dolomite; medium to coarsely crystalline; sandy and cherty.

Middle Cambrian ?

Cbs
BUFFALO SPRINGS FORMATION
Interbedded light to pinkish gray limestone and dolomite; cryptozoon reefs near top, sandy in part.

Lower Cambrian

Ct
TOMSTOWN FORMATION
Massive dolomite with thin shaly interbeds.

Chl Ch
HARDYSTON FORMATION
Quartzite and quartzitic sandstone; Chl - basal conglomerate.

PRECAMBRIAN

DIABASE
Altered, light to dark gray, probably Precambrian in age.

p
Pegmatite and associated aplite.

GRANITE GNEISS
Includes pegmatitic granite gneiss near Cornwall; also thin pegmatites and aplites, and as much as 20% assimilated or partly assimilated and injected hornblende gneiss.

qd
QUARTZ DIORITE GNEISS
Includes granodiorite.

HORNBLENDE GNEISS
Includes gabbro gneiss and minor biotite-hornblende gneiss.

GRAPHITIC GNEISS
Includes metasediments intermediate in composition between graphitic gneiss and hornblende gneiss.

MIGMATITES AND CLOSELY INTERBEDDED GNEISSES. THE FIRST LETTER INDICATES THE PREDOMINANT GNEISS, THE SECOND AND THIRD LETTERS THE SUCCESSIVELY MORE SUBORDINATE GNEISSES OF THE MIGMATITE.

Granite gneiss, with approximately 20 to 30% assimilated or partly assimilated and injected hornblende gneiss.

Granite gneiss with approximately 30 to 40% assimilated or partly assimilated and injected hornblende gneiss.

Granite gneiss with approximately 30 to 40% pegmatite or associated aplite.

Granite gneiss with approximately 30% pegmatite or associated aplite and 20% assimilated or partly assimilated and injected hornblende gneiss.

Granite gneiss with approximately 30 to 40% assimilated or partly assimilated and injected graphitic gneiss.

Quartz diorite gneiss with approximately 30 to 40% partly assimilated hornblende gneiss.

qdg
Quartz diorite gneiss with approximately 20 to 30% associated granite gneiss.

Hornblende gneiss injected, assimilated or replaced by approximately 20 to 30% granite gneiss.

Hornblende gneiss injected, assimilated or replaced by approximately 30 to 40% granite gneiss.

Hornblende gneiss injected, assimilated or replaced by 30 to 40% pegmatite.

Hornblende gneiss injected, assimilated or replaced by 30 to 40% granite gneiss and 10 to 20% pegmatite

Hornblende gneiss injected, assimilated or replaced by approximately 30% granite gneiss and 30% pegmatite

Graphitic gneiss injected, assimilated or replaced by 20 to 30% granite gneiss

Graphitic gneiss injected, assimilated or replaced by 30 to 40% granite gneiss

Graphitic gneiss interbedded with approximately 30% hornblende gneiss and injected, assimilated or replaced by approximately 30% granite gneiss

CONTACTS

Definite contact

Inferred contact

Concealed contact

STRUCTURE SYMBOLS

High angle fault, movement — U, up, and D, down

Fault, showing relative movement

Thrust, barbs on side of upper plate

Strike and dip of beds known to be right side up

Strike and dip of beds where it is not known which side is up

Horizontal bedding

Strike of vertical beds

Strike and dip of overturned beds

Strike and dip of cleavage

Horizontal cleavage

Strike and plunge of minor anticline, showing degree of plunge

Strike and dip of axial plane of minor overturned anticline

Strike and dip of foliation and plunge of lineation

Strike and dip of foliation

Strike and dip of joints

Strike of vertical joints

Horizontal joints

Trend of "smear" lineation developed on bedding plane

MISCELLANEOUS SYMBOLS

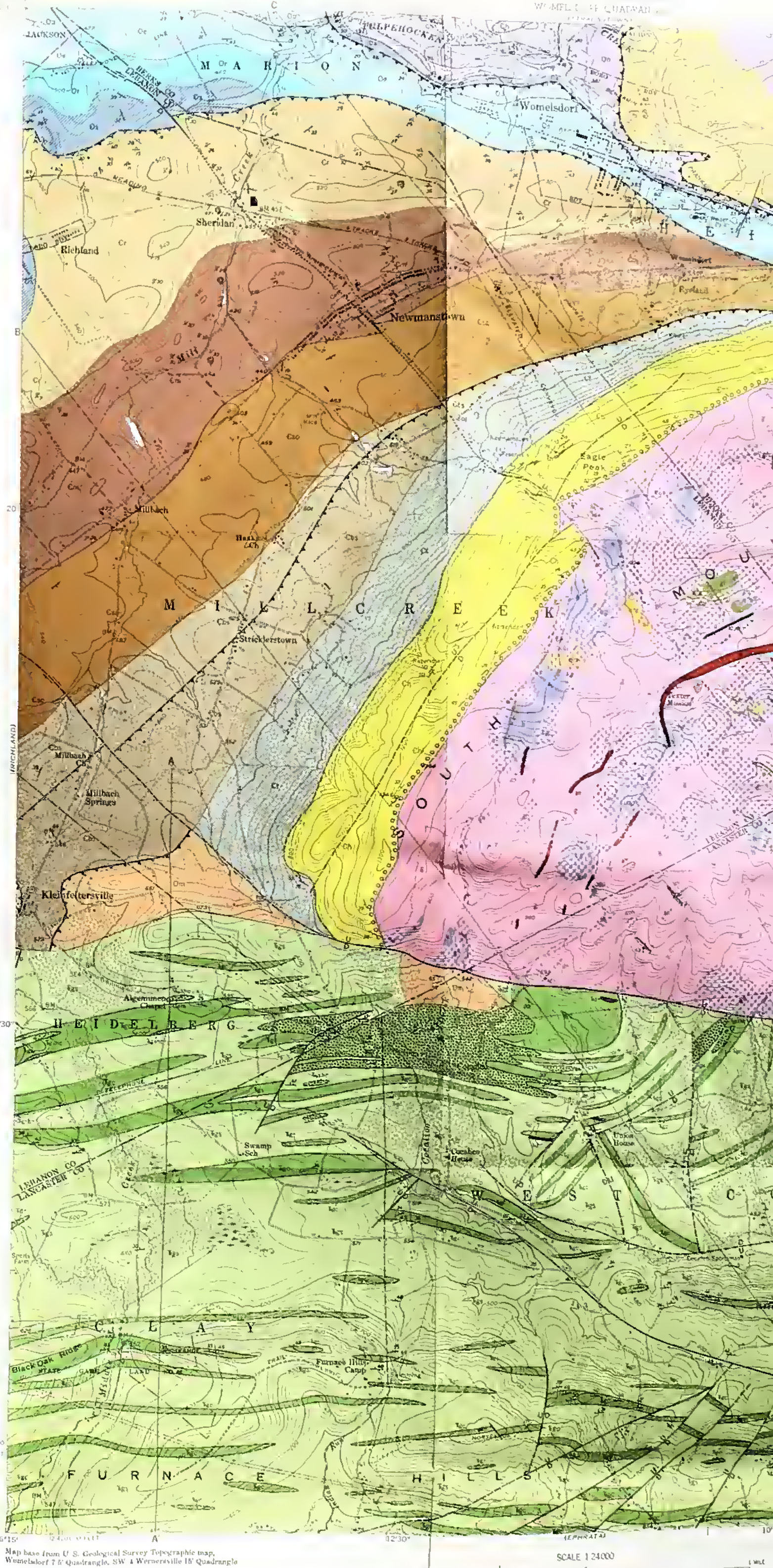
Quarry

Fossil occurrence

A — — A'
Line of cross section

Location diagram with index of areas mapped by co workers

DEPARTMENT OF INTERNAL AFFAIRS
Genevieve Blatt, Secretary



Map base from U. S. Geological Survey Topographic map, Womelsdorf 7.5' Quadrangle, SW ¼ Wernersville 15' Quadrangle

SCALE 1:24000

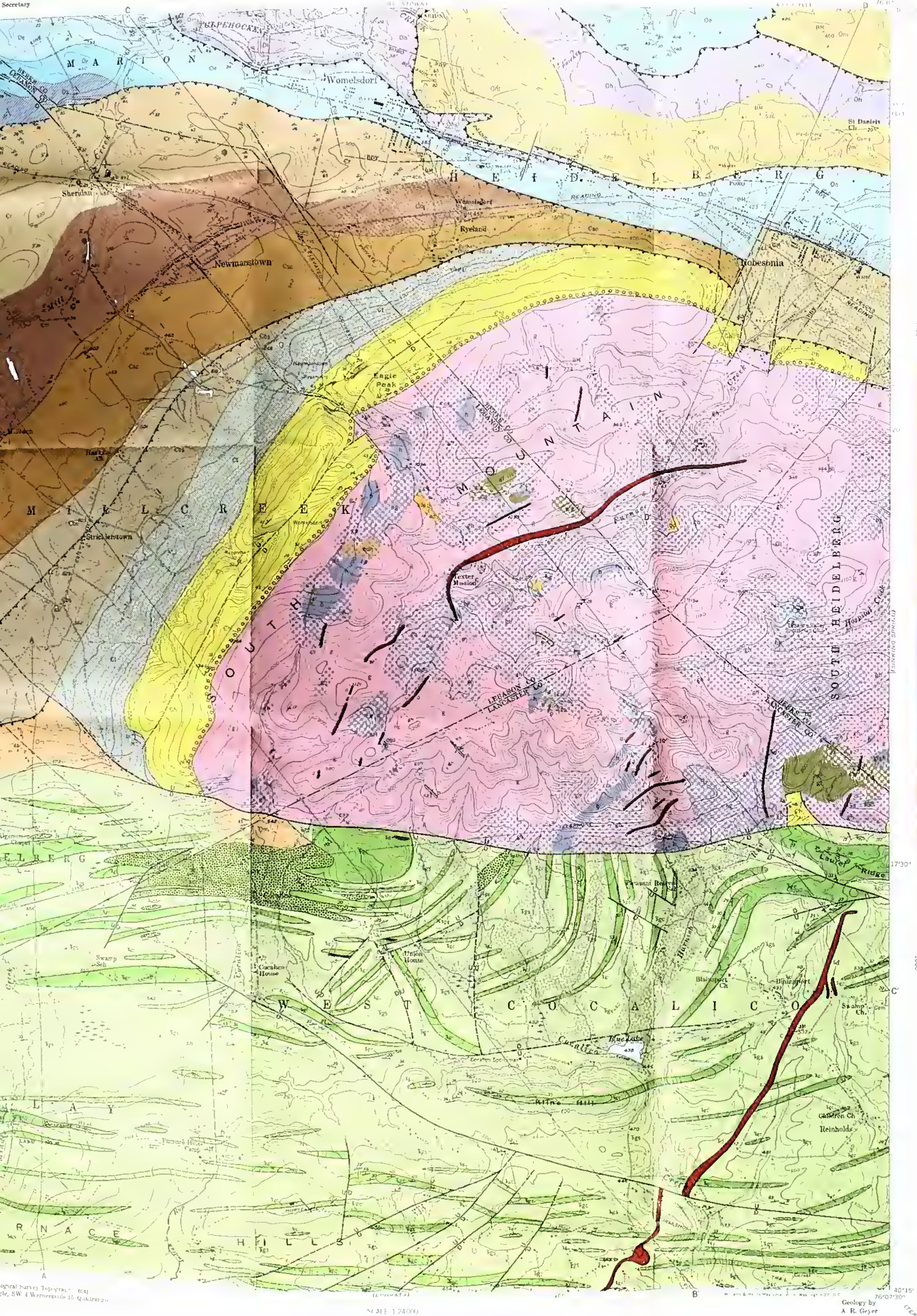
Contour interval 20 feet
Datum is mean sea level

GEOLOGIC MAP
OF THE
WOMELSDORF QUADRANGLE, PENNSYLV

1963

ERNAL AFFAIRS
Secretary

TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist



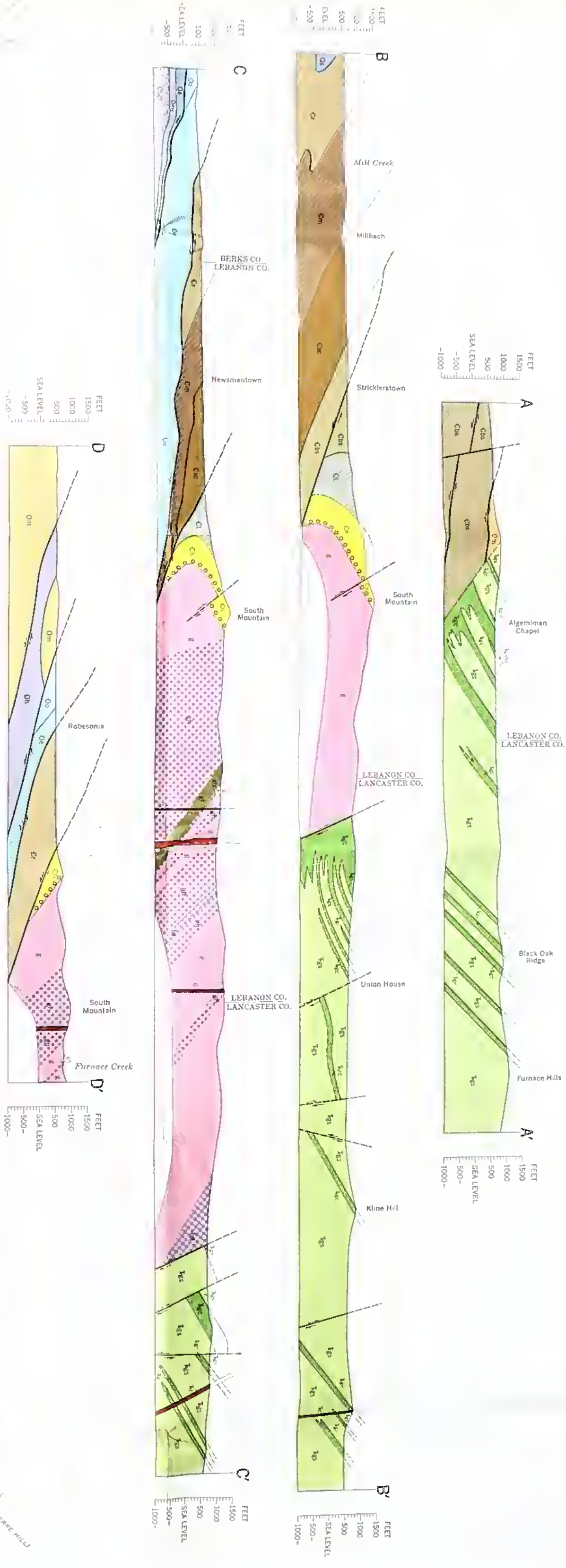
SCALE 1:24000

Contour interval 20 feet
Datum is mean sea level

Geology by
A. R. Geyer
T. V. Buckwalter
D. B. McLaughlin
Carlyle Gray

GEOLOGIC MAP
OF THE
WOMELSDORF QUADRANGLE, PENNSYLVANIA

1963



GEOLOGIC CROSS SECTIONS

ATLAS 177 C
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